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Site Evaluation Studies

of the

Massachusetts Bay Disposal Site

for

Ocean Disposal of Dredged Material

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prepared by  
William A. Hubbard  
Marine Ecologist

J. Michael Penko  
Biologist

Terrence S. Fleming  
Marine Ecologist

Environmental Resources Section  
Impact Analysis Branch

prepared for  
Thomas J. Fredette  
Senior Project Manager  
Marine Analysis Unit  
Compliance Section  
Regulatory Branch

New England Division  
U.S. Army Corps of Engineers  
424 Trapelo Road  
Waltham, Massachusetts 02254-9149

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| <p>The ecology of a deepwater (100 meter) dredged material disposal site is described. The physical, chemical, and biological impacts of disposal are analyzed based on historical data and <u>in-situ</u> sampling. A comprehensive management plan is discussed based on these findings (See also - Executive Summary)</p> |       |  |  |  |                                  |
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## EXECUTIVE SUMMARY

### Introduction

The purpose of this action is to synthesize the information necessary to evaluate the continued use of an interim ocean disposal site (Massachusetts Bay Disposal Site) in accordance with the criteria established in the Ocean Dumping Regulation (40 CFR 228.4 - 228.6). The site, located in Stellwagen Basin of Massachusetts Bay in approximately 60-100 meters of water, is an Environmental Protection Agency (EPA) approved interim dredged material ocean disposal site with a circular boundary of two nautical miles diameter as identified in the Federal Register as Marblehead (40 CFR 228.4 - 228.6). The center of the site (formerly referred to as the Foul Area Disposal Site) is at 42°25.7' north latitude and 70°34.0; west longitude, approximately 22 nautical miles east of Boston. This dredged material disposal site is centered one nautical mile east of an area previously used as a chemical disposal site.

The New England Division of the Corps of Engineers has disposed or permitted disposal of approximately 2.8 million cubic yards of dredged material at the Mass Bay Disposal Site (MBDS) over the past twelve years. Consideration of the designation of the site as a permanent Ocean Dredged Material Disposal Site will provide the Corps of Engineers and other public and private interests with a site of suitable size to accommodate the regional disposal need of areas generally ranging from Gloucester to Plymouth, Massachusetts, with occasional use by interests from greater distances.

The designation of an Ocean Dredged Material Disposal Site is the responsibility of the Administrator of the Environmental Protection Agency after consulting with Federal, State, and local officials, interested members of the general public and the Secretary of the Army. The designation of the Massachusetts Bay Disposal Site from an interim to a permanent status will be aided by the technical information contained in this document. The environmental suitability of the area as a permanent dredged material disposal site will be evaluated by the Administrator using the general and specific criteria established in the EPA Ocean Dumping Regulations and Criteria (33 USC 1401-1435; PL 92-532 as amended) and other pertinent regulations.

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Since the Massachusetts Bay Disposal Site is an interim or existing site, the focus of the evaluation is restricted to determining the continuing suitability of FADS as a regional disposal site, rather than evaluating alternative ocean disposal options. It is not the intent of this study to designate any additional areas of ocean bottom to receive dredged material. Only if this study shows that the existing site is unsuitable for continued use will other sites in the area be investigated. The suitability of this site for designation is based on the evaluation criteria of the Ocean Dumping Regulations (40 CFR 228). The designation of the site does not necessarily imply disposal will occur. All dredged material proposed for ocean disposal will continue to be evaluated on an individual project basis under existing regulatory reviews. Designation simply identifies the ocean disposal site that would normally be used when ocean disposal is determined from the individual-project review to be the best alternative for that project.

The New England Division, Corps of Engineers, has been conducting oceanographic sampling of MBDS since 1973. Various scientific organizations have conducted research for the Corps under the management of NED's Marine Analysis Unit, Compliance Section, Disposal Area Monitoring System (DAMOS). This program investigates all aspects of dredged material disposal in New England and actively monitors physical, chemical, and biological conditions at nine disposal sites throughout New England. A review of the DAMOS program reports for MBDS, along with pertinent scientific literature, was conducted to identify data gaps in the oceanographic knowledge of site specific conditions at this site. Extensive site evaluation studies were then contracted to fulfill the criteria of the Marine Protection, Research, and Sanctuaries Act of 1973 (40 CFR 228.5-6). Although this report describes the results of these studies, the DAMOS program is continuing to monitor and manage MBDS, and continuing to conduct scientific investigations of the site. The specific site designation study program methods and results can be found in the MBDS Site Designation Studies Data Report (SAIC, 1986).



## EXISTING CONDITIONS

### Physical Oceanography

#### Temperature and Salinity

The physical environment at MBDS is influenced by the coastal New England climate, low riverine inputs to the Massachusetts Bay system and the general circulation pattern of the Gulf of Maine. The water column at MBDS behaves in a manner typical of northeastern continental shelf regions, with isothermal conditions of approximately 5°C during the winter, giving way to stratified conditions with maximum surface temperatures on the order of 18°C and a strong thermocline at 20 meters during the summer months. The water column overturns during the late fall, returning to isothermal conditions. Salinity minima occur in late spring as a result of increased runoff, but vary only a few parts per thousand with most values ranging from 31 0/00 to 33 0/00.

#### Currents

Previous studies and the results of recent investigations in the vicinity of MBDS indicate that bottom currents are relatively low (< 20 cm/sec) under nearly all conditions, while mid-depth and surface currents may be higher. During strong northeast winter storms (i.e., approximately once every four years), the bottom currents near MBDS may increase in a southerly direction to maximum speeds of 30 cm/sec in response to sea surface set-up on the western boundary of Massachusetts Bay.

The tidal currents at MBDS are characterized by mean velocities near the surface of 15-20 cm/sec in NNE-SSW orientation which decrease with depth to lower velocity, less periodic currents near the bottom (generally < 10 cm/sec). The wave conditions in the vicinity of MBDS result from both local wind wave formation and propagation of long period waves (swell) generated on the adjoining continental shelf. The sheltering provided by the coastline severely limits wave generation from the westerly direction; waves from the westerly quadrants larger than 1.8 m (6 ft) occur only 0.5% of the time on an annual basis, and such waves over 3.7 m (12 ft) are virtually nonexistent. Conversely, waves from the easterly quadrant that are over 1.8 m (6 ft) occur 4.2% of the time, or nearly ten times more frequently, and waves over 3.7 m (12 ft) occur approximately 0.5% of the year.

### Bathymetry

The results of the bathymetry survey show that the topography of the disposal site is characterized by a relatively flat, featureless bottom throughout most of the site with the notable exception of steep shoaling in the northeast and northwest quadrants. The depths throughout the smooth, featureless area are on the order of 85-90 meters, with maximum depths occurring in a broad depression in the south central portion of the site. The shoals in the northeast quadrant, with minimum depths of 57 meters within the site, represent glacially-formed features and are associated with Stellwagen Bank to the east of the site. The smaller shoal in the northwest section of the survey is a small, circular rise which appears to be a single, separate feature, although derived in the same manner as Stellwagen Bank.

The bottom in the deeper portions of MBDS is a broad depression with natural sediments composed of fine grained silt. Shoal areas to the north and northeast are covered by coarser deposits. Dredged material has previously been deposited in the site over a relatively large area, but has not been altered or transported to any significant degree during the past several years. Recent disposal operations have shown that with adequate navigation, the spread of material on the bottom is approximately similar to that which would be expected in shallower water.

### Water Chemistry

The water column chemical concentrations of all metals at MBDS were found in concentration below the acute criteria (EPA, 1976) for marine waters. The average water column organic chemical contamination at MBDS exhibits low PAH and PCB concentrations.

## Sediment Chemistry

Recent and historical sediment chemistry determinations have identified various areas of Massachusetts Bay as depositional areas for time-ordered particulates emanating from throughout the system (Gilbert, 1976). Quiescent deepwater basins, such as Stellwagen Basin, are usually such areas. The 1985-1987 chemical sampling program has identified a reference (MBDS-REF) area that is unimpacted by trace metals from dredged material disposal. As would be expected, the disposal point itself (MBDS-ON) within MBDS shows statistically significant elevations in concentrations of chromium, copper, lead and zinc, as compared to the reference area. These metals reflect the most recent dredged material inputs and are generally in the moderate (Cr, Pb, and Zn) to low (As, Cu, Cd, Hg, and Ni) contamination categories of dredged material classification (MDWPC, 1978). The MBDS-OFF area, within the MBDS boundary but spatially remote from the dredged material disposal point, has levels that are comparable to the reference area. Therefore, significant elevations of metal contaminants are restricted to the point of disposal, and not impacting the MBDS-OFF or reference areas.

Organic chemical investigations at MBDS indicate elevated organic constituents at the disposal area on dredged material, but ambient level concentrations were found at the reference sites and in areas within MBDS but off dredged material. Carbon to nitrogen ratios averaged 11.6 (S.D.= 1.4, n=6) for the disposal point, and 8.6 (S.D.=0.08, n=6) for the reference site, which is relatively equivalent to the unimpacted site within MBDS at 8.7 (S.D.=0, n=3). Oil and grease levels were low (< 0.5%) but statistically ( $p < 0.05$ ) elevated at the disposal area at 1763.3 ppm (S.D.= 421.6, n=6), in comparison with the reference sediment concentration of 285 ppm (S.D.=87.0, n=5) and unimpacted areas within the site averaging 306 ppm (S.D.=131, n=3). Petroleum hydrocarbons were also quantitatively low but elevated on the dredged material site at 1513 ppm (S.D.=302.6, n=6) compared to reference levels of 244.4 ppm (S.D.=112.9, n=5) and MBDS-OFF of 327 ppm (S.D.=10, n=3).

PAH (Polycyclic Aromatic Hydrocarbon) compounds were undetectable throughout the study area except for 0.51 ppm of flouranthene at a site of recent disposal. Phthalate compounds, a plasticizer, was also detectable here at 7.64 ppm. Both of these values are typical of urban estuarine sediments.

PCB (Polychlorinated biphenyl) compounds were highly variable in sediment concentration with disposal station values averaging 0.414 ppm (S.D.=403, n=5) and unimpacted areas within MBDS averaging 0.073 ppm (S.D.=0.065, n=5). Reference area PCB concentrations reflected the "settling basin" nature of Stellwagen Basin averaging 0.061 ppm (S.D.=0.062, n=6), quantitatively similar to MBDS-OFF values.

### Tissue Residue

The examination of available polychaete, bivalve and crustacean tissue at MBDS exhibits low levels of metal residues and no statistical elevations over ambient (reference) residues. Organic residue levels data were generally highly variable and quantitatively low. One sample of Nephtys incisa tissue from January, 1986, on dredged material, exhibited an elevated PCB concentration of 0.52 ppm wet weight, however previous and subsequent sampling did not reveal similar contamination. PAH contamination was statistically elevated on areas of dredged material, in comparison to reference sites. Quantitatively, PAH levels were low, less than 2.5 ppm dry weight and predominantly influenced by benzo (a) anthracene and chrysene.

### Benthic Community Structure

The analysis of the benthic community structure in the vicinity of the MBDS revealed assemblages typical of Massachusetts Bay. The 1985 to 1986 sampling program identified the dominant organisms at the reference area to be the polychaete Paraonis gracilis, averaging 29.2% (S.D.=9.3, n=9) of all organisms and the polychaete Heteromastus filiformis averaging 10.1% (S.D.=4.7, n=9) of all organisms. Average overall benthic density for the three seasons investigated was 5,936 organisms per square meter (S.D.=2842.7, n=9) from an average of 44 species per square meter (S.D.=9.5, n=9).

The benthic population sampled in September 1985 from a silty area within MBDS, but off dredged material (MBDS-OFF) contained a similar dominance of Paraonis gracilis (18.9%) for its average density of 8746 organisms per square meter from 37 species (n=3). The dredged material station within MBDS was clearly dominated by oligochaetes in September 1985, comprising 24.7% of its 26,548 organisms per square meter from 55 species (n=3). These assemblages are typical for populations colonizing recently disturbed habitat, such as the dredged material, exploiting the available high organic content of the substrate.

The sandy reference area east of MBDS (MBDS-SRF) was dominated in September 1985 by the polychaete Exogone verugera, representing 15.4% of its 9190 organisms per square meter from 63 species (n=3). The sand station within MBDS (MBDS-NES) was also dominated by Exogone verugera, at 20.5% of its 4622 organisms per square meter from 69 species.

The results of the benthic population studies indicate the silty reference area and the area within MBDS not directly disposed upon have a similar benthic community structure. The disposal point benthic community is different than the reference area and unperturbed site even though the sediment facies are similar. High densities of annelids are colonizing the disposed dredged material in comparison to the ambient substrate at the silty reference site. Within MBDS, left off dredged material, there are higher densities of oligochaetes than at the silt reference site. This may indicate recruitment from MBDS-ON or another type of perturbation, possibly the foraging effects of organisms such as schools of dogfish observed in the finfish sampling program. The dogfish may have affected the benthic community structure in a manner similar to disposal, i.e. a temporary perturbation. The sandy area within MBDS was similar to the sandy reference area and both sites have typical Massachusetts Bay benthic communities.

### Finfish

Finfish studies suggest that substantial finfish resources occur in the vicinity of MBDS. The resident finfish community on mud bottom at MBDS is dominated by American plaice, Hippoglossoides platessoides; and witch flounder, Glyptocephalus cynoglossus. Silver and red hake, Merluccius bilinearis and Urophycis chuss, are abundant, commercially important seasonal migrants at MBDS. Hard bottom communities at MBDS (approximately 25% of total area) are probably dominated by redfish, Sebastes marinus; ocean pout, Macrozoarces americanus; cusk, Brosme brosme; and Atlantic wolffish Anarhichas lupus.

BRAT (Benthic Resource Assessment Techniques) studies suggest that some differences exist between fish communities on dredged material versus natural bottom. Food resource availability and food utilization patterns of dominant demersal fish may have been altered by previous dredged material disposal. The benthic community colonizing recently disposed dredged material are typically polychaete organisms of small body size, short life cycles and high numbers. These are preferred prey of small (mouthed) finfish in comparison to natural substrates with larger resident benthos.

### Mammals, Reptiles and Birds

Regionally, the Gulf of Maine is within the range of approximately 35 species of marine mammals, four species of marine turtles and approximately 40 species of seabirds. Dedicated aerial studies have been conducted by NED (MBO, 1987) to assess the site specific mammal, reptile, and seabird use of MBDS. While not exhaustive, the observations represent a characterization of the dominant species occurrence in the three ten minute square study area contiguous to MBDS. Threatened and endangered species of marine mammals and turtles, including the Humpback whale, Megaptera novaeangliae; the Fin whale, Balaenoptera physalus; and the Right whale, Eubalaena glacialis occur in the vicinity of MBDS.

Reptiles that potentially would occur at MBDS include the threatened loggerhead turtle, Caretta caretta; and the endangered Atlantic Ridley's turtle, Lepidochelys kempi; green turtle Chelonia mydas; hawksbill turtle, Eretmochelys imbricata; and leatherback turtle, Dermochelys coriacea. Site specific scientific studies in 1985-1986 identified non-endangered dominant marine mammals at MBDS to include the minke whale Balaenoptera acutorostrata; the white sided dolphin, Lagenorhynchus acutus; and the harbor porpoise, Phocoena phocena. Non-dominant mammals that may range into the Gulf of Maine (extralimittally) include pilot whales Globicephala melaena; grampus, Grampus griseus; killer whales, Orcinus orca; bottlenosed dolphins, Tursiops truncatus; common dolphins, Delphinus delphis; spotted dolphins, Stenella plagiodon; striped dolphins, Stenella coeruleoalba; harbor seals, Phoca vitulina; and gray seals, Halichoerus grypus. Dominant seabirds observed during these studies include northern fulmar, Fulmarus glacialis; shearwaters, Puffinus spp; storm petrels, Hydrobatidae; northern gannet, Sula bassanus; Pomarine Jaeger, Stercorarius pomarinus; gulls, Larinae; and alcids, Alcidae.

### Endangered Species

The Gulf of Maine waters are high-use habitat for fin, humpback and right whales between spring and fall. Winter concentrations of fin and humpback whales are reduced from the other times of the year. Winter distribution and abundance of right whales in the Gulf of Maine are poorly understood. Southwest-Gulf of Maine (Jeffreys Ledge, Stellwagen Bank south along the 100 m contour outside Cape Cod to the Great South Channel) is the subregion of highest use per unit area (greatest density) by large whales between Cape Hatteras, North Carolina and Nova Scotia. Species of endangered large whales use this area throughout the year, with densest concentrations occurring through fall.

The 10' latitudinal block east of the Massachusetts Bay Disposal Site (MBDS) study area occurs over the northwest corner of Stellwagen Bank, the area Kenney (1985) found to have the highest habitat-use index by cetaceans. The 10' quadrant that MBDS is located in also is an area of high cetacean use with a habitat-use index > 90-95th percentile. In this 10' square the actual 2 nautical mile diameter site has an areal coverage of approximately 5% of the total.

The five species of marine turtles that potentially would occur in the study area include the loggerhead turtle, Atlantic Riddleys turtle, hawksbill turtle, green turtle, and the leatherback turtle. Of these, Massachusetts Bay is considered marginal habitat for loggerhead and Atlantic Ridley's turtles. Green turtles and hawksbill turtles are rare or absent from Massachusetts Bay. The leatherback turtle would be the only species expected to occur in the study area, seasonally in late spring through summer, feeding opportunistically on jellyfish in the water column.

## Environmental Impacts

### Physical Oceanography

Physical alterations in substrate character associated with dredged material disposal are confined within the site. The MBDS station has been used for disposal of dredged material and other waste products for more than 50 years. Consequently, the center and western areas of the site are covered with dredged material deposits, characterized by a series of low broad topographic features. The dredged material deposits are relatively thin, broad layers consisting primarily of silts and some coarser sediments. There are localized regions with concentrations of cohesive clump deposits in the vicinity of disposal buoy locations.

The deposited dredged material appears to be very stable. Dredged material that had been in place for more than two years still displayed the reduced, high organic, black mud characteristic of dredged material from estuaries in the region. Side scan sonar and MBDS surveys also documented the distribution of dredged material and presence of cohesive clumps in areas where disposal had taken place several years earlier. Consequently, it is apparent that neither physical disturbance from currents and waves, nor sedimentation has significantly affected these deposits over the past two years.

### Currents

The water column at MBDS is characteristic of the shelf regime throughout New England, with strong stratification near the surface during the late summer and isothermal conditions during the winter. Near-surface currents in the area are dominated by tidal flow in northeast-southwest directions at 15 to 20 cm/sec, with maximum tidal velocities on the order of 30 cm/sec. Based on the results of the current meter deployment in September 1987, the mid-water depths experienced mean current velocities from 10 to 15 cm/sec with a dominant northwesterly flow. At the deeper depths, there was a secondary component to the southeast. Small amounts of fine-grained sediments separate from the dredged material plume during convective descent and remain in suspension. Annually, during periods when a well-developed pycnocline exists, these sediments could be concentrated at that level and potentially be transported away from the disposal point. The actual amount of this material will be determined by the physical characteristics of the sediment, the volume of material disposed, and method of disposal, but it could range from 3 to 5%. When the pycnocline is near the surface, net transport would be in a SW or NE direction. During the remainder of the year (i.e. late fall to mid-summer) the pycnocline will deepen then disperse with flows predominantly southwest through northwest direction.

Near-bottom currents are very low, averaging less than 7 cm/sec. Occasional higher velocities reaching up to 20 cm/sec in a westerly direction have been observed in near-bottom waters in response to easterly storm events occurring during the fall or winter. No strong bottom currents were observed as a result of storm events. Based on these data it is apparent that the near-bottom currents at MBDS are not sufficient to resuspend sediments. The wave regime in the vicinity of MBDS is controlled by the lack of fetch from a westerly direction and the fact that storms are duration-limited in their ability to generate waves. Since they generally approach the MBDS region over land from the south and west, northeast storms do not affect the waters of Massachusetts Bay until they are essentially at the site. Consequently the duration of these storms in Massachusetts Bay is quite short (maximum of 1-2 days). These limitations, combined with depth of the site ( $> 85$  m), greatly restrict the generation of waves capable of causing resuspension of dredged material at MBDS. In order to generate waves of sufficient height and period to cause resuspension, an easterly storm must have winds in excess of 50 mph for a period of more than 12 hours. Such storms are uncommon, potentially occurring at a maximum approximately once every four years in the Massachusetts Bay region. These occurrences are significant regional storms that generally do not persist. Their effects have been minimal on other disposal sites, e.g. Central Long Island Sound (in 20 meters of water), causing episodes of minor surficial erosion.

The combination of wind and wave conditions existing at MBDS and the evidence that previously deposited dredged material has remained unchanged over a several-year period all support the conclusion that MBDS is a containment site. Dredged material deposited at MBDS can be expected to remain in place for extended periods of time although surficial sediments may be resuspended on rare occasions of severe easterly storm events. During these events transport of the resuspended material would be to the west and southwest in combination with resuspended natural sediments.

### Capping

Management of dredged material at MBDS should emphasize navigation control of the disposal operation. Recent surveys at MBDS have shown that dredged material was restricted to an area with a radius of approximately 500 meters for a deposit of about  $250,000 \text{ m}^3$  placed in the vicinity of a taut moored buoy. Tighter control of the scows with respect to disposal in close proximity to the buoy could potentially reduce this areal coverage further. Capping of contaminated sediments at MBDS will require point disposal at a taut moored buoy, but it is an effective option for management of contaminated dredged material at MBDS.



### Chemical Impacts

Review of the historical disposal data, the water column chemistry, the within site versus ambient sediment chemistry and the biotic tissue residue levels, indicates that disposal of dredged material at MBDS imparts a chemical signature in a low to moderate (Cr, Cu, Pb and Zn) range for sediments and low range for tissue residue. Water quality impacts are temporally limited to the immediate disposal event. The balance between pre-disposal chemical and biological testing and in situ sampling agrees well and defines correlation in test results. Contaminant levels are being appropriately identified by bulk chemical screening. The statistically significant biological availability of contaminants at the disposal point seems to be restricted to persistent organics, particularly PAHs. However, even though statistically elevated the actual levels are quantitatively low.

### Benthic Impacts

The benthic community of the MBDS reference area (MBDS-REF) is similar to typical Massachusetts Bay and Stellwagen Basin communities (species complexes of Prionospio / Paraonis spp. and Thyasira sp.). There is a clear impact of dredged material disposal on the benthic community at the disposal point. MBDS-ON (the disposal point) was dominated by oligochaetes and Spio pettibonae. These organisms are the pioneers, or rapid recolonizers, of disturbed areas and efficiently exploit substrate niches of high organic content. The summary statistics demonstrate the high oligochaete dominance at the dredged material disposal point. The silty reference area (MBDS-REF) benthic community was comprised of similar species with a considerably lower density than the disposal point. The area within MBDS, but not on disposed dredged material (MBDS-OFF) was similar in abundance and composition to the reference site differing predominantly in the presence of oligochaetes. The sandy stations (MBDS-SRF and -NES) had corresponding similar benthic communities for the coarser grained substrate. These benthic studies reflect a change in community structure is generally confined to the disposal point within MBDS.

### Fisheries Impacts

The approximately 4.2 square mile MBDS area represents an insignificant percentage (< 1%) of the total area available for ground fishing and shellfishing in Massachusetts Bay. Continued disposal of dredged material at MBDS will have no significant impact on the region's marine resources. Adverse impacts to individual organisms will occur, but be insignificant outside the immediate vicinity of the disposal site. Similarly, any changes in community structure related to impacts on benthic food resources will be highly localized and insignificant to fisheries resources on a regional basis.

### Plankton Impacts

The disposal of dredged material at MBDS will not significantly impact the plankton population of Massachusetts Bay. Localized (approximately 10-20 hectare) spatial impacts on plankton of short (< 4 hours) temporal duration will potentially result from elevated suspended solids concentration. The elution of chemical contaminants in significant concentrations affecting plankton is highly unlikely.

Similarly conservative impact estimates predict average annual elevations in suspended solid load (>100 mg/l) to impact a total of 0.7 square miles for approximately a total of approximately 14 days of the year. Chemical elution and subsequent water column dilutions, are not expected to yield significant levels and in fact would only exceed the EPA Quality Criteria for Water in a small percentage (<1%) of the MBDS water column prior to dilution below criteria. Sedimentary chemical contaminants are disposed at the site in various concentrations and are only found in low to moderate in situ concentrations. These results indicate potential interference with phytoplankton and zooplankton productivity would be minimal.

### Endangered Species

The continued disposal of dredged material at MBDS is not likely to have any significant impact on endangered species prey, critical habitat or the species themselves. In particular, suspended solids and contaminant inputs to the water column do not have the potential to significantly impact the water column outside the disposal site boundary. Contaminant levels in prey species such as sand lance, Ammodytes dubius or A. americanus, are indicative of Massachusetts Bay-wide background contamination. No evidence of significant contaminant remobilization exists with regard to dredged material disposal at MBDS. Turtle prey items, e.g. jellyfish, crabs etc., are also not anticipated to be significantly impacted due to their remoteness from the point of disposal and the limited spatial and temporal disposal impact persistence. Current vectors have not been identified as having the potential to transport contaminants to any significant endangered species critical habitat. Finally, the tug and barge activity would not be anticipated to interfere significantly with endangered species, given the organisms abilities to avoid the traffic, and the minimal activity at MBDS in comparison to the nearby Boston Harbor traffic lanes.

From a physical, chemical, and biological oceanographic standpoint, the designation of MBDS as a disposal site for dredged material would appear to be an appropriate continuing use of this portion of Massachusetts Bay. It is apparent that material deposited at the site will remain in place, and since the area has previously been used for disposal of dredged material and other waste products, such a designation would not expand the area of the seafloor affected by future disposal operations.

In summary, the intensive oceanographic evaluations performed at MBDS throughout this and previous studies indicate that continued use of the site for dredged material disposal will have minimal environmental impacts. As scientific understanding of oceanographic processes evolves and as future DAMOS monitoring results advise, the management of MBDS will be continually reassessed.

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## CHAPTER 1. PURPOSE AND NEED FOR ACTION.

### A. General

The purpose of this action is to synthesize the information necessary to evaluate the continued use of an interim ocean disposal site in accordance with the criteria established in the Ocean Dumping Regulation (40 CFR 228.4 - 228.6). The information developed in this technical document will be used to designate the Massachusetts Bay Disposal Site (MBDS) as an area of ocean bottom for receiving dredged material. The designation of this site will confine the impacts of dredged material disposal and associated environmental alterations to a spatially limited area.

The site, located in Massachusetts Bay (see Figure 1-1) in water ranging from approximately 60-100 meters deep, is an Environmental Protection Agency (EPA) approved interim dredged material ocean disposal site with a circular boundary of two nautical miles diameter as identified in the Federal Register as Marblehead (40 CFR 228.4 - 228.6). The center of the site is at 42°-25.7' north latitude and 70°-34.0' west longitude, approximately 22 nautical miles east of Boston, 14.5 nautical miles southeast of Manchester Bay, Manchester, 26 nautical miles northwest of Race Point, Provincetown, and ten miles south-southeast of Eastern Point, Gloucester, Massachusetts. This disposal site has historically been called the "Foul Area" because of the many fishing net "hangs" that could foul the equipment.

Open water disposal sites provide an alternative disposal method for dredged material generated from the maintenance of the navigability of ports and waterways and the improvement of harbor and channel facilities. The suitability of these sites is a function of their environmental acceptability and economic feasibility.

Designation of a disposal site only results in availability of the site to receive dredged material. Actual disposal of sediments would take place only after the material has been specifically evaluated (see Section 5B, 5C) and open-water disposal has been chosen as the best option.

### B. Corps of Engineers National Purpose and Need.

Title I of the Marine Protection Research and Sanctuaries Act (MPRSA) of 1972, Section 102, requires the Corps of Engineers to evaluate Federal dredged material disposal activity and permit the transportation of dredged material for the purpose of ocean disposal according to the impacts of these activities. This evaluation considers effects on human health, welfare and amenities and impacts on the marine environment, ecological systems, and economic feasibility. One of the missions of the Corps of Engineers is to maintain the navigability of waterways under authority of the various River and Harbor Acts. This mission includes the disposal of dredged material in an ecologically and economically acceptable manner.



The Massachusetts Bay Disposal Site has been designated as an interim dredged material disposal site since 1977 although it has been used for disposal of various substances since 1940 (see Chapter 1E1 - Site History). The determination of its environmental acceptability is critical to its designation for permanent status. The permanent designation of this site for dredged material disposal is in the national interest to allow for continued economical maintenance of navigable waterways.

#### C. Corps of Engineers Local Purpose and Needs (Federal Projects and Private Permits).

The harbors of New England require maintenance dredging on a regular basis due to the accumulation of shoaling material. The authority for maintenance dredging is delegated to the Corps under various River and Harbor Acts. Improvement dredging is authorized in response to expanding needs of individual ports. The New England Division of the Corps of Engineers has disposed or permitted disposal of approximately 2.8 million cubic yards of dredged material at the Massachusetts Bay Disposal Site over the past twelve years. The material was from harbors, rivers and channels between Gloucester and Plymouth, Massachusetts. A majority of this material was silt (60%) while approximately 40% was sand and gravel. The volume and type of material historically disposed here can be projected for future needs. Table 1-1 contains a list of rivers and harbors that have the potential to use this site for disposal of dredged material over at least the next five decades. Designation of the Massachusetts Bay Disposal Site as a permanent Ocean Dredged Material Disposal Site will provide the Corps of Engineers and other interests with a site of suitable size to accommodate the regional disposal need of areas from Gloucester to Plymouth, Massachusetts.

Other potential alternatives that could accept the large volumes of sediments that will require disposal are either economically and/or logistically limited for most projects and practical purposes. The next closest interim designated disposal site is Cape Arundel Disposal Site which is 45 miles from Gloucester and the closest designated site is the Portland Disposal Site which is 68 miles from Gloucester. There are no regional upland disposal sites that are currently available. To meet a 50-year need of disposal (approximately 15 million cubic yards), upland sites totalling 390 acres would be needed (not including acreage needed for dikes, treatment facilities, etc.) if these sites were to be covered with a layer of dredged material 26 feet deep. Prior studies of available upland disposal sites have identified potential sites that would only accommodate a small fraction of the projected need (Sasaki Associates, 1983).

#### D. Environmental Protection Agency's Purpose and Need.

The designation of an Ocean Dredged Material Disposal Site is the responsibility of the Administrator of the Environmental Protection Agency

after consulting with Federal, State, and local officials, interested members of the general public and the Secretary of the Army. The designation of the Massachusetts Bay Disposal Site from an interim to a permanent status will be aided by the technical information contained in this document. The environmental suitability of the Massachusetts Bay Disposal Site as a permanent dredged material disposal site will be evaluated by the Administrator using the general and specific criteria established in the EPA Ocean Dumping Regulations and Criteria (MPRSA) and other pertinent regulations.

#### E. Regional Disposal Needs.

##### 1. Site History

The general vicinity of the Massachusetts Bay Disposal Site (MBDS) has received industrial waste, e.g. intentionally sunken derelict vessels, organic and inorganic compounds, and construction debris since the 1940's. Earlier disposal actions were not at a specified point, but a considerable distance from land as judged by the vessel skipper. Most dredged material was disposed at sites closer inshore than MBDS especially at a location called the "Boston Lightship Disposal Site" (see Figure 1-1). Some dredged material that was considered "contaminated" (often without any chemical testing) was disposed in the vicinity of the offshore area eventually termed the "Massachusetts Bay", the subject of this study.

The disposal site marker "A" buoy was deployed by the U.S. Coast Guard at 42°-26.8'N and 70°-35.0'W from August 1963 through January 29, 1975. In 1975, at the request of the Corps, the buoy was moved into deeper waters at its present location (42°-25.7N and 70°-35.0'W). In 1977, the Ocean Dumping Regulations (40 CFR 220 - 229) established the dredged material disposal site as an overlapping two nautical mile diameter circle centered one nautical mile east (42°-25.7N and 70°-34.0'W) of the previous industrial waste site (see Figure 1). This reconfigured site is used only for the disposal of dredged material and has received approximately 2,800,000 cubic yards of dredged material between 1977 and 1985, a majority of which came from Boston Harbor dredging projects.

##### 2. Composition

Often the material that settles in channels and harbors in New England is fine grained sediments that are not suitable for fill, beach nourishment or other constructive practices. This material is transported by river bedload, storm water runoff, and tidally driven currents to settle in areas of low current velocities. This settling creates shoals that must be periodically dredged to ensure the safety of vessels navigating harbor channels and anchorages. Additional dredging occurs in response to improvement needs of various harbors.

The predominantly silt and sandy-clayey-silt that needs to be disposed from Massachusetts harbors must have a low energy environment for

stability in containing the disposed material within the designated site. During the past disposal activities at MBDS, 62.1% of all material was silt and clay (greater than 4 phi), 37.3% was sand (-1 to 4 phi), and the remaining 0.6% was gravel (less than -1 phi). Much of the material disposed was a mixture of sandy silt which has been contained in place at MBDS because of the stable nature of this deepwater offshore area. Disposal in shallow nearshore sites could allow storm activity to resuspend dredged silts and clays. Upland disposal sites are few and expensive on this urban coastline. Presently, there are no public access upland or nearshore disposal alternatives in the greater Boston Region, and private alternatives are of limited viability (Sasaki Associates, 1983). Recent investigations by the Commonwealth of Massachusetts are determining the feasibility of establishing a dredged material containment island in Boston Harbor. This site, however should only be used for contaminated material that does not pass disposal evaluation testing (i.e. bioassay/bioaccumulation testing - EPA/COE, 1977).

Historically, since approximately the 1940's the chemical composition of a majority of materials disposed in the ocean MBDS was not analyzed. Recent practices of testing have revealed that dredged material of varying composition was disposed at MBDS as represented in Table 1-2 since 1976. Caution should be used in interpreting these data, since the perceived need to test material biases the results, i.e. material from non-polluted, and therefore non-tested, harbor areas are not considered in the average. In general, the tests were concentrated on surficial sediments in the most polluted section of project areas. Maintenance dredging usually removes recently accumulated surficial sediments. Improvement dredging projects generally remove deeper layers of uncontaminated materials. The deeper layers generally receive little or no testing and could represent the majority of a project's disposed material.

### 3. Geographic Extent of Harbors Using the Site.

The use of the Massachusetts Bay as a disposal site by dredging projects in specific harbors is dependent on the "zone of economic feasibility" a term used to define an area within economic haul distance to the site. Table 1-1 lists the harbor projects that currently have the potential to dispose of dredged material at MBDS. In general, all rivers, channels and harbors from Gloucester through Plymouth, Massachusetts, that are dredged, have the potential to generate material that would be disposed at MBDS. Historically the majority of material in cubic yardage has come from Boston Harbor (67%) with those harbors south of Boston comprising 20% of the material disposed at MBDS. The remaining 13% was generated from dredging projects in harbors north of Boston to Gloucester, Massachusetts.

### 4. Projected Needs for Disposal.

The Massachusetts Bay is designated as an interim disposal site and provides a disposal alternative to the dredging needs of the greater

Boston region. These dredging projects generate approximately 230,000 cubic yards annually to be disposed at MBDS (see Table 1-2). Occasionally projects such as Boston Harbor Federal channel maintenance dredging have generated up to 1.6 million cubic yards of sandy-clayey-silt to be disposed at MBDS. It is anticipated that the future needs for disposal of dredged material will be equivalent to the previous regional needs of approximately three million cubic yards per decade. Recent proposals for infrastructure and harbor improvements in the greater Boston area may triple these projections in any one decade. The Massachusetts Bay Disposal Site will be evaluated in this document for its suitability in meeting these needs.

TABLE 1-1

Harbors, rivers, and channels that have the potential (are within an economically feasible haul distance) to dispose of dredged material at MBDS.

Rockport Harbor and Pigeon Cove  
Gloucester Harbor  
Annisquam River and Smith Cove  
Essex River and Castle Neck River  
Ipswich River and Eagle Hill River  
Rowley River  
Manchester Harbor  
Beverly Harbor  
Danvers, Crane, and Porter Rivers  
Salem Harbor  
Marblehead Harbor  
Lynn Harbor  
Swampscott River  
Winthrop Harbor  
Saugus/Pines River  
Malden River  
Mystic River  
Boston Harbor  
    Chelsea River  
    Fort Point Channel  
    Little Mystic (South) Channel  
    Boston Inner Harbor  
    Charles River  
    President Roads Anchorage  
    Reserve Channel  
    Main Ship Channel (Board Sound, North, South, and Narrows Channel)  
    Nubble Channel  
    Island End River  
    Dorchester Bay and Neponset River  
    Weymouth Fore, Town, and Back Rivers  
    Allerton Harbor  
    Hingham Harbor  
Weir River including Nantasket Channel and Sagamore Cove  
Cohasset Harbor  
Scituate Harbor  
Green Harbor  
Duxbury Harbor  
Kingston Harbor  
Plymouth Harbor and Cordage Channel

Table 1-2a. Disposal Volumes (cubic yards and cubic meters) for MBDS (Volumes are barge estimates-in place factor is approximately 0.65 - Tavalaro, 1985)

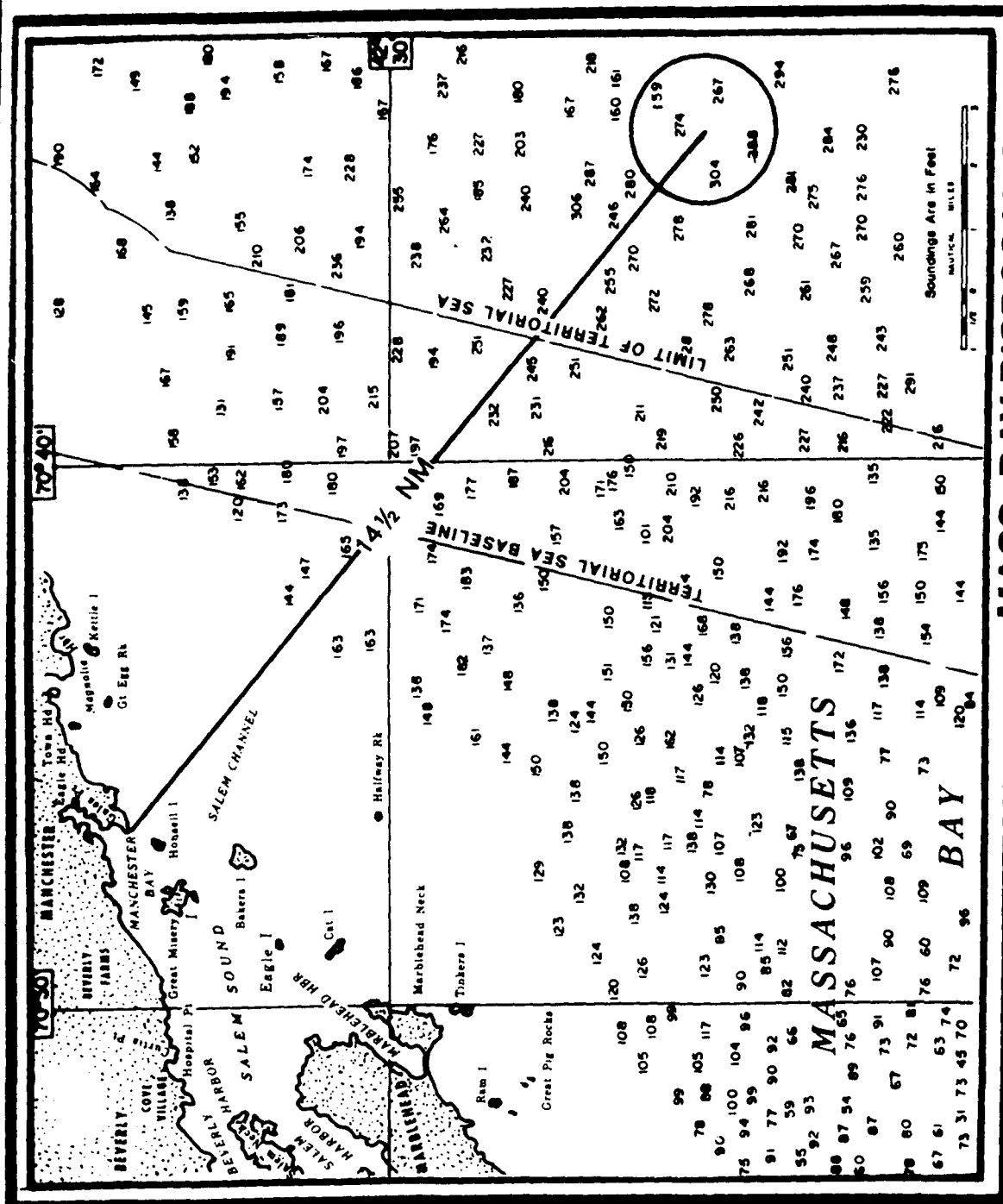
| YEARLY TOTALS | C.Y.      | C.M.      |
|---------------|-----------|-----------|
| 1987          | 118,800   | 90,834    |
| 1986          | 232,122   | 177,480   |
| 1985          | 273,355   | 209,007   |
| 1984          | 226,369   | 173,081   |
| 1983          | 282,919   | 216,320   |
| 1982          | 845,819   | 646,713   |
| 1981          | 315,204   | 241,004   |
| 1980          | 15,108    | 11,552    |
| 1979          | 91,908    | 70,273    |
| 1978          | 33,116    | 25,320    |
| 1977          | 50,223    | 38,400    |
| 1976          | 313,558   | 239,746   |
| GRAND TOTALS  | 2,798,502 | 2,139,730 |

Table 1-2b. Statistical Summary and Weighted Average of all Dredged Disposal at MBDS between 1976 and 1987.

Concentrations are in ppm (dry weight)

|                                 | Hg   | Cd    | Pb     | Cr     | Cu     | Ni     | Zn     | As    | PCB  | %Vol  | %Cl  |
|---------------------------------|------|-------|--------|--------|--------|--------|--------|-------|------|-------|------|
| AVG. ppm                        | 0.58 | 2.02  | 96.50  | 88.17  | 65.31  | 24.08  | 134.70 | 8.44  | 0.25 | 2.08  | 1.09 |
| STD                             | 0.90 | 2.19  | 106.62 | 116.32 | 84.12  | 24.28  | 145.91 | 11.34 | 0.62 | 2.44  | 1.77 |
| MAX                             | 6.46 | 8.90  | 491.50 | 629.50 | 448.50 | 88.83  | 532.00 | 52.10 | 3.00 | 8.23  | 7.48 |
| Mass Class III is greater than: | 1.50 | 10.00 | 200.00 | 300.00 | 400.00 | 100.00 | 400.00 | 20.00 | 1.00 | 10.00 | 1.00 |
| Weighted Average                | 0.68 | 2.96  | 126.84 | 105.88 | 104.60 | 36.76  | 170.83 | 12.63 | 0.22 | 2.99  | 2.13 |
| Mass Class II is greater than:  | 0.50 | 5.00  | 100.00 | 100.00 | 200.00 | 50.00  | 200.00 | 10.00 | 0.50 | 5.00  | 0.50 |

Note: Massachusetts Classification guidelines are from 314 CMR 9.00.



## MASS. BAY DISPOSAL SITE

Description: This site is a circular area with a diameter of 2 nautical miles and center at 42°-25.7'N, 70°-34.0'W. From the center, the Marblehead Tower bears true 282° at 24,300 yards and Baker Island Horn bears true 300° at 24,300 yards. The authorized disposal point (within the overall disposal area) is specified for each dredging project in other project documents. Depth Range: 159 to 304 feet MLW

NOTE: The map depicts the disposal site's location in relation to landmarks. It is not intended for use in navigation.

Figure 1-1  
Massachusetts Bay  
Disposal Site

## CHAPTER 2. SITE EVALUATION STUDIES

A. Authority. The scientific investigations associated with the designation of the Massachusetts Bay Disposal Site are being conducted in accordance with the requirements of the Marine Protection, Research and Sanctuaries Act of 1972 (86 Stat. 1052) (MPRSA) as amended (33 U.S.C.A. 1401 et seq.) and the EPA's Ocean Dumping Regulations and Criteria (40 CFR 220-229). The site evaluation study was designed in accordance with the joint EPA and Corps of Engineers draft workbook entitled "Technical Guidance for the Designation of Ocean Dredged Material Disposal Sites" (EPA/COE, 1983).

The purpose of the MPRSA is to regulate the transportation of material to be disposed beyond the territorial sea baseline. MBDS position 10 nautical miles off the Massachusetts coast places disposal here in ocean water beyond the territorial sea. Section 102 (a) of this Act establishes the criteria to evaluate the environmental effects from disposal of dredged material and designation of recommended sites. This criteria empowers the administrator of the EPA to designate sites for ocean disposal. Under Section 103 of this Act, the Secretary of the Army may issue permits for the transportation of dredged material for the purpose of disposing into ocean waters, when the Secretary of the Army determines, with the EPA's concurrence, that the disposal will not unreasonably degrade the marine environment.

Following the intent of the Marine Protection, Research and Sanctuaries Act of 1972, the Corps of Engineers, New England Division, has undertaken an extensive oceanographic survey of the Massachusetts Bay Disposal Site. The specific investigations have incorporated interdisciplinary scientific analyses to address the criteria with respect to this law and the guidelines established in the EPA's Ocean Dumping Regulations and Criteria (40 CFR 220-229). The Massachusetts Bay Disposal Site is therefore being proposed as a permanent ocean disposal area for dredged material from Federal navigation projects and from non-Corps dredging projects permitted under the criteria established in Section 103 of this Act. The general and specific criteria of the Ocean Dumping Regulations (40 CFR 228) are addressed below in detail for the Massachusetts Bay Disposal Site.

The guidance given in the EPA/COE Draft Site Designation Workbook (EPA/COE, 1983) offers three phases for the designation process. Phase I is entitled "Collection of Data and Screening". Phase II is "Data Synthesis and Preliminary Decisions" and Phase III consists of the "Technical Guidance". Since the Massachusetts Bay Disposal Site is an interim or existing site, the evaluation of its suitability is based on Phase III Technical Guidance. The first two phases involve establishing alternative sites from "zones of feasibility". This process is not applicable to this study since the MBDS site is active. It is not the intent of this study to designate any additional areas of ocean bottom to receive dredged material. Only if this study shows that the existing site



is unsuitable for continued use will other sites in the area be investigated for designation. The Phase III portion of the designation process establishes its evaluation criteria from the criteria of the Ocean Dumping Regulations (40 CFR 228).

#### B. General and Specific Criteria for Site Evaluation

The designation of this interim site must be examined in accordance with the Regulations 40 CFR 228.5 and 228.6. To support continued use of the site for dredged material disposal, scientific analyses must be documented to substantiate these criteria. The purpose of this document is to compile the necessary scientific information to evaluate the interim status of this site.

##### 1. General Criteria (40 CFR 228.5)

a. The dumping of materials into the ocean will be permitted only at sites or in other areas selected to minimize the interference of disposal activities with other activities in the marine environment, particularly avoiding areas of existing fisheries or shellfisheries, and regions of heavy commercial or recreational navigation.

b. Locations and boundaries of disposal sites will be chosen so that temporary perturbations in water quality or other environmental conditions during initial mixing caused by disposal operations anywhere in the sites can be expected to be reduced to normal ambient seawater levels or to undetectable contaminant concentrations or effects before reaching any beach, shoreline, marine sanctuary, or known geographically limited fishery or shellfishery.

c. If at any time during or after disposal site evaluation studies, it is determined that existing disposal sites presently approved on interim basis for ocean dumping do not meet the criteria for site selection set forth in section 228.6, the use of such sites will be terminated as soon as suitable alternative disposal sites can be designated.

d. The sizes of ocean disposal sites will be limited in order to localize for identification and control any immediate adverse impacts to permit the implementation of effective monitoring and surveillance programs to prevent adverse long-range impacts. The size, configuration, and location of any disposal site will be determined as a part of the disposal site evaluation or designation study.

e. EPA will, wherever feasible, designate ocean dumping sites beyond the edge of the continental shelf and other such sites that have been historically used.

## 2. Specific Criteria (40 CFR 228.6)

The oceanographic program established in 1985 by NED in cooperation with other pertinent groups and agencies to monitor the area and assess impacts of disposal, was initiated to analyze the site in accordance with the following specific criteria:

- a. Geographic position, depth of water, bottom topography, and distance from coast.
- b. Location in relation to breeding, spawning, nursery, feeding, or passage areas of living resources in adult or juvenile phases.
- c. Location in relation to beaches or other amenity areas.
- d. Types and quantities of wastes proposed to be disposed of and proposed methods or release, including methods of packaging the waste, if any.
- e. Feasibility of surveillance and monitoring.
- f. Dispersal, horizontal transport, and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any.
- g. Existence and effects of present or previous discharges and dumping in the area (including cumulative effects).
- h. Interference with shipping, fishing, recreation, mineral extraction, desalination, fish, and shellfish culture, areas of special scientific importance, and other legitimate uses of the ocean.
- i. The existing water quality and ecology of the site as determined by available data or by trend assessment or baseline surveys.
- j. Potentiality for the development or recruitment of nuisance species in the disposal site.
- k. Existence at or in close proximity to the site of any significant natural or cultural features of historical importance.

The evaluation of MBDS, based on all available data, in accordance with these criteria, is summarized in Table 2-1 - Site Evaluation Guidance - Conflict Matrix, as recommended in Reese and Chesser, 1985.

Table 2-1

## Site Evaluation Guidance - Conflict Matrix (Reese and Chesser, 1985)

| Factor of Consideration                                    | Interaction | Comments   | Compliance        |                  |
|--|-------------|--|-------------------|------------------|
|  |             |  | Specific Criteria | General Criteria |
| 1. Unusual topography                                      | NC          |  | a,f,j,k           | a                |
| 2. Physical sediment compatibility                         | BU          | Create (rock) habitat                                  | c,d,i             | b,c,d,           |
| 3. Chemical sediment compatibility                         | PC          | see 3.B.2 and 4.B.2                                    | c,d,g,i           | a,b,c,d          |
| 4. Influence of past disposal                              | BU          | Cover old disposal                                     | e,g,i,s<br>b,c    | a,b,d            |
| 5. Living resources of limited distribution                | NC          |  | f,h,k             | a,b,d            |
| 6. Commercial fisheries                                    | PC          | See 3.C.2 and 4.C.2                                    | b,h,              | a,b              |
| 7. Recreational fisheries                                  | NC          |  | b,h,              | a,b              |
| 8. Breeding /spawning areas                                | NC          |  | b,h,              | a,b              |
| 9. Nursery areas   | NC          |  | b,h,              | a,b              |
| 10. Feeding /passage areas                                 | NC          |  | b,h,              | a,b              |
| 11. Critical habitats of threatened or endangered species. | PC          | 5.5km from Stel-lwagon Bank<br>See 3.C.5 and 4.C.5     | b,h               | a,b,             |
| 12. Spatial distribution of benthos                        | PC          | shift to<br>Pioneering sere<br>See 3.C.3 and 4.C.3     | b,h,j             | a,b,             |
| 13. Marine mammals   | PC          | usually mammals<br>avoid barges<br>See 3.C.4 and 4.C.4 | b,h,              | a,b,             |

|   |    |  |               |         |
|---|----|--|---------------|---------|
| 14. Mineral deposits  | NC |  | a,h           | a,b,e   |
| 15. Navigation hazard                                       | NC |  | a,h,          | a,b,d   |
| 16. Other uses of ocean<br>(cables, pipelines,<br>etc.)     | NC |  | h,            | a,b,d   |
| 17. Degraded areas  | PC | East of industrial<br>waste disposal site<br>See 1.E.1 | d,f,g         | a,b,d   |
| 18. Water column<br>chemical/physical<br>characteristics    | NC |  | d,f,i         | a,b,d   |
| 19. Recreational uses                                       | NC |  | b,h,k         | a,b,c,d |
| 20. Cultural<br>/historic sites                             | NC |  |               |         |
|   |    |  | k             | b       |
| 21. Physical oceanography<br>waves/circulation              | NC |  | a,c,f,g       | a,b,d   |
| 22. Direction of trans-<br>port potential for<br>settlement | NC |  |               |         |
|   |    |  | a,c,f,g       | a,b,d   |
| 23. Monitoring  | NC |  | e             | c       |
| 24. Shape/size of<br>site (orientation)                     | NC |  | a,d,g         | d       |
| 25. Size of buffer zone                                     | NC |  | b,c,<br>d,g,k | b,d     |
| 26. Potential for<br>cumulative effects                     | NC |  | d,g           | c,d     |

C = Conflict

NC = No Conflict

PC = Potential Conflict

BU = Beneficial Use

### CHAPTER 3. AFFECTED ENVIRONMENT

The New England Division, Corps of Engineers, has been conducting oceanographic sampling of MBDS since 1973. Various scientific organizations have conducted research under contract to NED, including Sub Sea Surveyors, Inc. (1973); Cape Ann Society (1974); Northeastern University (1974); New England Aquarium (1974-1977); Naval Underwater Systems Center (1977); Marine Surveys Incorporated (1985); HMM Associates (1986); and Science Applications International Corporation (1980 to 1987). The studies contracted to these organizations were and are continuing under the management of NED's Marine Analysis Unit, Compliance Section, Disposal Area Monitoring System (DAMOS)(see also Chapter 5). This program investigates all aspects of dredged material disposal in New England and actively monitors physical, chemical, and biological conditions at nine disposal sites throughout New England. A review of the DAMOS program reports for MBDS, along with pertinent scientific literature, was conducted to identify data gaps in the oceanographic knowledge of site specific conditions at MBDS. Upon completion of this review, extensive site evaluation studies were contracted to fulfill the criteria of the Marine Protection, Research and Sanctuaries Act of 1973 (40 CFR 228.5 - 6). Although this report describes the results of these studies, the DAMOS program is continuing to monitor and manage MBDS, and continuing to conduct scientific investigations of the site.

The field operations conducted to supplement the site designation studies are listed in Table 3-1. The specific program methods and results can be found in SAIC 1987 (MBDS Site Designation Studies Data Report). The discussion of these results are included in the following chapters for each discipline.

TABLE 3-1  
FIELD STUDIES AT MBDS  
1985 THROUGH 1987  
(For earlier studies see Section 6. References)

#### PHYSICAL

|   |   |   |
|---|---|---|
| Bathymetric Surveys                                 | - | October 1985<br>January 1987  |
| Current Meters<br>(deployed)                        | - | June through August 1985<br>September through November 1985<br>February through April 1986<br>October through November 1987 |
| Current Meters<br>(Direct Reading DRCM)             | - | June, July, August, October 1985<br>January, February, March, and<br>April 1986<br>September and October 1987               |
| Side Scan Sonar Surveys                             | - | October 1985, November 1987   |
| REMOTS (sediment/water<br>interface profile camera) | - | June and September 1985<br>January 1987   |

|   |    |  |               |         |
|---|----|--|---------------|---------|
| 14. Mineral deposits  | NC |  | a,h           | a,b,e   |
| 15. Navigation hazard                                       | NC |  | a,h,          | a,b,d   |
| 16. Other uses of ocean<br>(cables, pipelines,<br>etc.)     | NC |  | h,            | a,b,d   |
| 17. Degraded areas  | PC | East of industrial<br>waste disposal site<br>See 1.E.1 | d,f,g         | a,b,d   |
| 18. Water column<br>chemical/physical<br>characteristics    | NC |  | d,f,i         | a,b,d   |
| 19. Recreational uses                                       | NC |  | b,h,k         | a,b,c,d |
| 20. Cultural<br>/historic sites                             | NC |  |               |         |
|   |    |  | k             | b       |
| 21. Physical oceanography<br>waves/circulation              | NC |  | a,c,f,g       | a,b,d   |
| 22. Direction of trans-<br>port potential for<br>settlement | NC |  |               |         |
|   |    |  | a,c,f,g       | a,b,d   |
| 23. Monitoring  | NC |  | e             | c       |
| 24. Shape/size of<br>site (orientation)                     | NC |  | a,d,g         | d       |
| 25. Size of buffer zone                                     | NC |  | b,c,<br>d,g,k | b,d     |
| 26. Potential for<br>cumulative effects                     | NC |  | d,g           | c,d     |

C = Conflict

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|   |   |   |
|---|---|---|
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| Current Meters<br>(deployed)                        | - | June through August 1985<br>September through November 1985<br>February through April 1986<br>October through November 1987 |
| Current Meters<br>(Direct Reading DRCM)             | - | June, July, August, October 1985<br>January, February, March, and<br>April 1986<br>September and October 1987               |
| Side Scan Sonar Surveys                             | - | October 1985, November 1987   |
| REMOTS (sediment/water<br>interface profile camera) | - | June and September 1985<br>January 1987   |

## CHEMICAL

|  |   |   |
|--|---|---|
| Sediment Chemistry<br>(including physical<br>analyses) | - | June and September 1985<br>January 1986<br>September 1987 |
| Water Chemistry  | - | June and September 1985<br>January and March 1986         |
| Tissue Residues  | - | June and September 1985<br>January 1986<br>September 1987 |

## BIOLOGICAL

|   |   |   |
|---|---|---|
| Benthic Community<br>Structure (0.1m <sup>2</sup> Smith-<br>McIntyre) | - | June and September 1985<br>January 1986 |
| Finfish Sampling<br>(Trawls and Demersal<br>Gill Nets)                |   | June and September 1985<br>January 1986 |
| Benthic Resource<br>Assessment Technique<br>(BRAT)                    | - | September 1985                          |

## GENERAL

|                                    |   |           |
|------------------------------------|---|-----------|
| Manned Submersible<br>Observations | - | June 1986 |
|------------------------------------|---|-----------|

### A. Physical Characteristics

This section discusses the physical characteristics of the Massachusetts Bay Disposal Site (MBDS) and the surrounding environment in terms of its overall setting in the Gulf of Maine and Massachusetts Bay. A thorough review of existing literature relevant to MBDS was conducted, and in-situ measurements were made during the summer and fall of 1985, winter of 1986, and fall of 1987 to supplement this general information with site-specific data.

#### 3.A.1 Climate

The climate in the vicinity of MBDS is influenced by three major factors: the prevailing west to east atmospheric flow, northward and southward fluctuations of tropical and polar air masses on this eastward flow, and the location on the east coast. The first two factors create a relatively high degree of variability in the weather patterns as warm, moist air from the south alternates with cool, dry air from the north. Throughout the year, but particularly during winter, the tracks of low pressure systems (northeasters) frequently follow the coastline, causing rain or snow and gale winds. Heavy fog occurs on an average of two days per month, and precipitation occurs on the average of one day in every



three. A summary of the climatic conditions over a twenty-year period for the coastline west of the disposal site is presented in Table 3.A.1-1 (U.S. Department of Commerce, 1979).

The wind systems affecting the region adjacent to MBDS display a regular seasonal variability. Wind data for the Massachusetts Bay Area which are summarized in Figure 3.A.1-1 (Metcalf and Eddy, 1984) indicate that in the winter months (November through March) the dominant wind direction is northwest while during the warmer months the dominant direction is strongly from the southwest. Winds over 25 mph occur most frequently from the northwest between December and March.

These prevailing wind patterns are perturbed throughout the year by the passage of short duration, high energy, low pressure storm events which follow the coastal track described earlier. These systems, typically rich in easterly winds generate the highest velocity winds affecting the area. This effect is shown in Figure 3.A.1-2 (Hayes et al., 1973). The wind rose on the left of the figure presents a yearly average of the data presented in Figure 3.A.1-1 and clearly displays the dominance of northwest and southwest winds, with a very small component from the northeast quadrant. However, the maximum wind velocities shown on the right of the figure indicate that nearly all strong winds (in excess of 40 mph) occur from the northeast and easterly directions.

### 3.A.2 Oceanography

The Massachusetts Bay Disposal Site is located in the northeast portion of Massachusetts Bay which is considered a western extension of the Gulf of Maine. The oceanography of the area is controlled by three major factors: the climate, as discussed above; the lack of significant river drainage into the bay; and the circulation of the Gulf of Maine. The Gulf of Maine circulation patterns in the vicinity of MBDS are modified to a large extent by the presence of Stellwagen Bank on the eastern margin of the Bay which blocks the exchange of water at depth with the Gulf and the shelf beyond. The absence of a major source of freshwater means that the water column exhibits characteristics of an open shelf environment.

#### 3.A.2.a Water Masses, Temperature and Salinity

The temperature/salinity cycle of Massachusetts Bay is characterized by seasonal variability, with maximum temperatures occurring in a stratified water column during August and September and minimum temperatures occurring in an essentially isothermal water column in January and February. Bumpus (1974) presented annual temperature and salinity profiles from the vicinity of the Boston Lightship (Figure 3.A.2-1) approximately 10 NM southwest of MBDS which demonstrated the structure of the temperature/salinity regime. These data are presented as Figures 3.A.2-2 and 3.A.2-3. The relationship of these data to MBDS is demonstrated through cross sections obtained over the northeast quadrant of Massachusetts Bay as shown in Figures 3.A.2-1 and 3.A.2-4.

These data indicate a minimum temperature in an isothermal water column of approximately  $5^{\circ}\text{C}$  occurring during the winter months and an extreme high temperature approaching  $17-18^{\circ}\text{C}$  in a highly stratified column during the late summer. The thermocline occurs at a depth of approximately 15 meters with the sharpest thermal gradient ranging from  $15^{\circ}$  to  $10^{\circ}\text{C}$  over a 5 meter depth interval to 20 meters. Below 20 meters, the water cools gradually to a nominal bottom temperature of  $4^{\circ}$  or  $5^{\circ}\text{C}$ . The stratification breaks down through vertical mixing during October and the water column is essentially isothermal from November until April.

The annual salinity cycle presented in Figure 3.A.2-3 follows the expected pattern with minima in both the surface and bottom waters occurring in the late spring. As would be expected, the surface salinities are less than the bottom values and show a much greater range of fluctuation, particularly in the spring months when variations in the amount of runoff can have an effect. Surface salinities expected at MBDS would have a maximum ranging between 32 and  $33^{\circ}/\text{oo}$  during the winter months and minimums on the order of  $31^{\circ}/\text{oo}$  during the spring. The bottom water is much more consistent, varying slightly around  $32^{\circ}/\text{oo}$ . Bigelow (1927) was the first to document the seasonal cycle of salinity in Massachusetts Bay and Butman (1977) described in detail the changes in water column parameters in the middle of Massachusetts Bay ( $42^{\circ}20'\text{N}$ ,  $70^{\circ}35'\text{W}$ ) occurring during the spring runoff of 1973. Figures 3.A.2-5 and 3.A.2-6 indicate vertical profiles of temperature and salinity occurring between March and June of that year. The change from a well mixed water column in March and April to the start of a stratified system with a developing thermocline at 15-20 meters is clearly seen in these figures. The reliability of these data in terms of conditions at MBDS is demonstrated in Figures 3.A.2-7, 3.A.2-8, and 3.A.2-9 which show the distribution of surface salinity on a seasonal basis (Bumpus, 1974). From these charts it is apparent that the salinity gradient parallels the coastline and, as expected, the surface salinities vary from a minimum of  $30^{\circ}/\text{oo}$  in May to  $32^{\circ}/\text{oo}$  during the winter months. The springtime minimum reflects the increased river runoff prevalent at that time of year, but is not as pronounced as may be observed at other shelf locations.

Prior to this program, the most site specific data obtained at MBDS were collected by Gilbert (1975) at six stations distributed throughout the original "Massachusetts Bay Foul Area". The results of his study, taken during December 1973 and April, July, and October 1974, are presented in Table 3.A.2-1. These data agree quite closely with the Bumpus (1974) data for the Boston Lightship except that they are higher in both temperature and salinity during the summer months. Surface temperatures of more than  $20^{\circ}\text{C}$  may reflect a small temporal variation in the upper water column during the sampling period and are not abnormally high values. The salinity of  $34^{\circ}/\text{oo}$  however, is higher than expected from previous work.

Temperature and salinity data obtained with a Neil Brown Direct Reading Current Meter (DRCM) during this program are presented in Appendix

I (Figure I-1) and appear consistent with the expected results. During June a small mixed layer was present to a depth of approximately 10 meters at 12°C. The thermocline was beginning to form as a broad temperature gradient between 10 and 50 meters with a minimum temperature of 6°C. Below 50 meters, the temperature gradually decreased to a minimum of 5°C. During July, August and September 1985 (Figure I-1), the absolute values of the temperature data are correct; however, the gradients appear to be smoothed as a result of the instrument being lowered faster than the response time of the thermistor. The surface temperature in July had warmed to 14.5°C and reached a maximum of 17°C during August and September. Throughout this period the bottom water remained at 6°C. The October profile displays a pronounced mixed layer to a depth of 25 meters with a constant temperature of 14°C. Below the mixed layer a sharp thermal gradient can be seen to the maximum depth attained at 50 meters. This cast was taken on a day with strong northwest winds which would have increased the mixing of the upper water column. Finally, during the winter months, the water column was essentially isothermal with the temperature of approximately 5°C.

Additional evidence of the stratified thermal structure occurring at MBDS is shown by the temperature data obtained from the current meters deployed at the site during September and October in 1985 and 1987 as shown in Figures 3.A.2-10a and b. In 1985, there was a decrease in both the absolute temperature and the variability of the record from surface to bottom. The temperature decreased from 17°C at the surface to approximately 7°C at the bottom. The greatest variability in temperature occurred at the 35 meter depth, where small oscillations, induced by tidal currents, caused large variability in the temperature record (up to 2°C). Because this meter was located in the thermocline, the steep temperature gradient resulted in this characteristic signature. Above and below the thermocline the variability of the temperature was much less.

An important observation in this record was the impact of Hurricane Gloria which occurred on 27 and 28 September 1985. The passage of this storm resulted in a decrease of surface temperature and marked increase in subsurface temperatures for a short period of time. This phenomenon is most likely a combination of turbulent mixing near the surface and transport of warmer water into the subsurface layers. The fact that all records returned to essentially pre-storm conditions indicates that no major overturn of the water column occurred as a result of this event.

In September 1987, additional arrays of current meters were deployed at the Massachusetts Bay Disposal Site. Prior to deployment, a CTD cast was made (Figure I-2) to document the water column structure and determine the depth of the thermocline for the proper placement of the current meters. The top ten meters of the water column had a temperature of approximately 15.5°C to 16°C. Below this layer to about 20 m, the temperature decreased sharply to approximately 5°C. A temperature of 4.5°C was found to be fairly constant to the bottom (92 m). Based on these results, current meters were deployed at 8, 25, 55, and 84 meter

depths. The temperatures recorded by the current meters during the first days of deployment compared almost exactly to those obtained with the CTD cast (Figure 3.A.2-10b and Appendix Figure I-2). This structure was maintained until 20 September when a storm event passed through the area and mixed the upper layer of the water column to below the 25 m current meter, removing the normal tidal fluctuations. This storm began on 18 September when average wind speeds exceeded 20 mph and peak velocities reached 40 mph from the NE and continued until 21 September (National Weather Service, Boston, personal communication). After approximately eight days, the water structure began to recover but never returned to those initial conditions. The effect of this storm at the 55 m depth was observed as tidal fluctuations in the sea temperature caused by the water column mixing. There was no significant effect seen at the bottom.

The only temperature record obtained from the winter deployment at MBDS (Figure 3.A.2-11) indicates a bottom temperature slightly above 4°C with little variability throughout the record. Again, this is consistent with the expected values as discussed above.

The salinity measurements obtained by the DRCM during this study (Figure I-1 in the Appendix) also follow the expected distribution and tend to support the observations of Gilbert (1975). During September and October, the salinity increased with depth from 31.5‰ at the surface to 32.5‰ near bottom. During the winter months, the data are essentially constant with depth at 33‰. These salinities are slightly higher than the values observed by Bumpus (1974), but consistent with those of Gilbert (1975).

In summary, the water column at MBDS behaves in a manner typical of northeastern continental shelf regions, with isothermal conditions of approximately 5°C during the winter, giving way to stratified conditions with maximum surface temperatures on the order of 18°C and a strong thermocline at 20 meters during the summer months. The water column overturns during the late fall, returning to isothermal conditions. Salinity minima occur in late spring as a result of increased runoff, but vary only a few parts per thousand with most values ranging from 31‰ to 33‰.

### 3.A.2.b Circulation: Currents, Tides and Waves

Water circulation in Massachusetts Bay is strongly influenced by the counterclockwise flow, or gyre, displayed by the Gulf of Maine (Figure 3.A.2-12) (Bigelow, 1927; Sutcliffe et al., 1976; Brown and Beardsley, 1978; Harris, 1972). Local tidal currents (mean tidal range 2-3 meters) and wind driven currents complicate the normal counterclockwise water movements (Bumpus, 1974; Parker and Pearce, 1973; Padan, 1977). Studies of circulation in Massachusetts Bay (Butman, 1977) have demonstrated the following key features: current speeds are primarily a function of semi-diurnal rotary tides, currents can be dominated by wind stress, particularly in winter, density distributions established during spring runoff can also alter the normal current field.

On a large scale, circulation within Massachusetts Bay is one component of the overall Gulf of Maine system (Figure 3.A.2-12). The circulation of the Gulf consists of two circular gyres, one counterclockwise within the interior of the Gulf, and the second, clockwise over Georges Bank. Massachusetts Bay waters are included as the western portion of the counterclockwise gyre within the Gulf. Previous studies using drift bottles and sea-bed drifters (Bigelow, 1927; Bumpus, 1976) indicated seasonal variability in this circulation under the combined effects of local wind stress and input of freshwater inflows. In general, the circulation gyres are most strongly developed in the summer; during the winter, the interior gyre tends to move northward and becomes more diffuse (Bumpus & Lauzier, 1965) (Figure 3.A.2-13).

Modeling efforts (Csanady, 1974) have suggested that the double gyre system can be predicted simply by the effects of surface wind stresses acting in combination with the bottom friction. Furthermore, the strength of the circulation field varies in response to the input of lower salinity waters and vertical mixing rates while the direction is largely dependent on wind direction.

As a result of these regional circulation characteristics and the variability of the local meteorological regime, Massachusetts Bay can be expected to have a general counterclockwise circulation with a moderate degree of temporal and spatial variability. In the immediate vicinity of MBDS, the long term currents would be expected to be generally in a southerly direction. Drifters released near the crest of Stellwagen Bank were recovered along the eastern shore of Cape Cod, while those released on the western margin of the Bank were recovered in Cape Cod Bay (Schlee et al., 1973). In all cases, the drift velocities were very low, ranging from 2 to 10 cm/sec.

The low frequency surface currents in the vicinity of MBDS can flow to the northward, during the spring months, because they are on the western margin of a clockwise-flowing gyre surrounding a lens of lighter, fresher water introduced from the eastern side of the basin. This freshwater is not derived from local sources but from the discharge of the Merrimack River into the Gulf of Maine.

Shorter time scale variability is dominated by the semi-diurnal component of the local tide field in which tidal currents are more developed and stronger within the shallow nearshore area. Riser and Jankowski (1974) noted that the general trend of tidal flow at the Boston Lightship Dumping Ground was southeasterly after high tide and northwesterly after low tide. These observations agree closely with those of Bumpus (1974) for the entire Massachusetts Bay including the MBDS area.

The near-bottom circulation of the Massachusetts Bay varies primarily as a function of topography, with highest values observed over crest regions of topographic features such as Stellwagen Bank and lowest values observed in the depressions located in the central portion of the Bay.

Observations by Schlee et al. (1973) indicated velocities on the crest remained below 20 cm/sec. These velocities suggest that winnowing of fine particles and/or erosion of coarser sediments can occur on the topographic features, but that deposition of fine materials would be expected in the basin areas.

Gilbert (1975) observed bottom currents within the MBDS area that were extremely low (less than 10 cm/sec) but had higher velocities at more shallow depths in the water column (Table 3.A.2-2). Butman (1977) deployed a bottom current meter approximately 5 NM south of MBDS and found similar conditions, with average speeds of approximately 5 cm/sec and maximum values less than 20 cm/sec 99% of the time but approaching 30 cm/sec under extreme conditions. Tidal components of these currents reached values of only 6 cm/sec oriented in an east-west direction. Current measurements made under the DAMOS program (NUSC, 1979) also indicated extremely low current velocities, generally less than 10 cm/sec (Figure 3.A.2-14).

Butman (1977) deployed several bottom current meters for a one year period throughout Massachusetts Bay and was able to characterize the response of the bottom currents to meteorological events during the winter. During other months of the year, Butman found no relation between bottom currents and meteorological events. During strong easterly storm events, the response of sea level and of bottom currents are related. The local sea surface setup is toward the west and is superimposed on absolute changes in the level of the Bay, controlled primarily by the response of the Gulf of Maine to the storm. Local sea surface set-up requires approximately one hour, while complete Bay-wide set-up requires 6-12 hours. During this sea surface set-up, the currents flow in the direction of the wind (westward) in shallow near-shore waters and opposite to the wind (eastward) in the deep basin areas. These bottom currents are affected somewhat by the topography of the Bay, in particular Stellwagen Bank, so that they are expected to flow more southeasterly in the vicinity of MBDS. The wind-driven deep currents are established approximately 12 hours after the wind stress is applied and remain essentially constant for the duration of the storm.

Measured changes in sea level (Bohlen, 1981) associated with major winter storm events (Table 3.A.2-3) show local set-up of more than 2.5 meters can occur with strong easterly winds in excess of 45 mph. Figure 3.A.2-15 presents a generalized view of the bottom current circulation associated with such easterly storms (Butman, 1977). Note that while flow on the crest of Stellwagen Bank is in the direction of the wind, the bottom currents in the basin near MBDS are southeasterly with much lower velocity.

In summary, previous studies in the vicinity of MBDS indicate that bottom currents are relatively low (<20 cm/sec) under nearly all conditions, while mid-depth and surface currents may be higher. During strong northeast winter storms (i.e., approximately once every three

years), the bottom currents near MBDS may increase in a southerly direction to speeds of 30 cm/sec in response to sea surface set-up on the western boundary of Massachusetts Bay.

Previous investigations (Metcalf and Eddy, 1984; Butman, 1977; Gilbert, 1975; Bumpus, 1974; and Schlee et al., 1973) in conjunction with the recent NED site investigations indicate MBDS to be a quiescent environment with low bottom currents. The NED sampling conducted during 1985-1987 obtained on-site current meter data for September 1985, February 1986, and September 1987. The fall 1985 deployment successfully measured surface and bottom current velocities and the February deployment successfully measured bottom current velocities. The September 1987 deployment successfully measured current velocities at four depths throughout the water column with duplicate meters at each depth. Because the records at each depth were essentially identical, they are discussed as being one record.

The characteristics of the current velocity field at MBDS are presented as frequency distribution tables (Appendix Tables I-1 to 7) and time series plots of current speed and direction (Figures 3.A.2-16 to 22). For the near-surface (10 m) measurements (Figure 3.A.2-16) taken during the fall of 1985, the mean speed was 22 cm/sec with peak tidal velocities averaging approximately 35 cm/sec, except during Hurricane Gloria. Near bottom (82 m) current speeds for the same period (Figure 3.A.2-17) had a mean value of 7 cm/sec, but had two distinct periods with different characteristics. Prior to Hurricane Gloria on 27 September 1985, the bottom current speeds were oscillatory in nature with mean speeds on the order of 20 cm/sec. Following the storm, the oscillations became less periodic and reduced in speed to an average of 4-5 cm/sec.

Near bottom (85 m) measurements made during the winter of 1986 (Figure 3.A.2-18) were similar to the second portion of the fall measurements with very low currents averaging 4 cm/sec for most of the record. During this deployment, two peaks are shown in the current speed reaching 60 cm/sec on 21 March 1986. These data are considered invalid for three reasons:

- 1) no other measurements in this vicinity (Butman, 1977; Gilbert, 1975; NUSC, 1979; Schlee et al., 1973) have observed maximum bottom currents greater than 30 cm/sec.
- 2) no significant meteorological event could be correlated with the high currents.
- 3) the current meter array was severely damaged and all instruments above the lowest meter were lost, most likely through contact with a trawler.

Therefore, it is assumed that the trawler dragged the mooring creating an anomalous reading. This is further confirmed by the

temperature record (Figure 3.A.2-11) which displays a rapid increase in temperature at the same time as the current meter peaks. This would indicate that the meter was lifted off the bottom into slightly warmer water.

The surface current meter record in the fall of 1987 indicates a dominant flow in the SW direction approximately 56% of the time with mean velocities of approximately 15 cm/sec. For about 40% of the time, a NE flow occurs with a mean velocity of 11 cm/sec. Peak velocities of 72 cm/sec and 53 cm/sec with very short duration occurred in the SW and NE directions, respectively. On 20 September 1987, the effects of a storm event can be seen as the elimination of the normal tidal oscillations in the surface layer for the next four days. Current velocities reached a maximum value of 72 cm/sec in a SSW direction on 21 September. The Neil Brown Acoustic Current Meter was deployed at the surface during this survey specifically to eliminate the potential for erroneous current velocity measurements associated with wave action. Because a winged current meter was deployed at the surface during the 1985 survey, that data may reflect the effects of wave action, especially during Hurricane Gloria, and should be considered less accurate as to the actual conditions.

A similar effect of the storm can be seen in the current meter record for the 25 m depth, although the peak velocity was less (56 cm/sec). The dominant flow at this depth was in the SW quadrant for approximately 65% of the time at mean current velocities of 15 cm/sec. For the remainder of the time, current directions were in the other three quadrants approximately 10% of the time at mean velocities of 10-13 cm/sec. The current meter record for the 55 m depth indicated a dominant flow in the NW quadrant for 46% of the time with mean current velocities of approximately 10 cm/sec. For 30% of the time, a flow in the SE quadrant occurred, also with mean velocities of 10 cm/sec. Peak velocities at this depth of 23 cm/sec occurred during the storm event on 21 September, although tidal oscillations were not significantly affected. At the near-bottom meter (84 m), all current velocities were less than 4 cm/sec for over 85% of the time. A weak but dominant flow occurred in the WNW direction with the secondary flow to the ENE. These data match very closely those obtained during the 1985 deployment. In contrast to the effect of the passage of Hurricane Gloria where tidal oscillations were suspended, the only effect of the present storm event was to reduce the range of current direction from NW to NE.

During all deployments, the three-hour low-pass (3-HLP) current velocity data (Figures 3.A.2-16 to 22) indicate that the short-term current fluctuations are dominated by the semi-diurnal tidal component, as expected, and that the absolute value of the current velocities are greater near the surface than in the bottom waters. Tidal ellipses for all seven records (Figure 3.A.2-23) indicate a strong NE-SW orientation for the surface water. During 1987, this orientation was extremely restricted with no evidence of rotational flow. This feature was



originally thought to be an instrument malfunction, but extensive analysis of both meters at the 8 meter depth has determined this data to be valid. Bottom waters have a slight E-W orientation during the fall and a nearly rotational flow during winter. Peak tidal velocities in the surface layer averaged approximately 16 cm/sec, reaching a maximum of 70 cm/sec during the passage of Hurricane Gloria and the storm of 18 September 1987.

The expected development of southeasterly bottom currents in response to easterly storm events is not seen in the bottom current meter record during Hurricane Gloria (Figure 3.A.2-17). The bottom current clearly changes from the initial tidal fluctuations during this period and maintains a westerly flow for approximately a 24 hour period. This is also shown in the forty-hour low pass (40-HLP) vector plot (Figure 3.A.2-24) which displays a net westerly drift during the period of the storm. Once the storm event passed, the net current transport remained extremely low. During the September 1987 deployment, the strong NE winds created westerly flow in the top 25 m of the water column but had no strong effect on bottom currents.

During the winter deployment (Figure 3.A.2-18), several small perturbations to the oscillatory flow occur which may be related to meteorological events. On 16 February 1986, a small peak velocity of 20 cm/sec occurs associated with the only easterly wind activity to occur in February (4 days from 16-20 February; maximum speed-17 mph) which was associated with a low pressure cell passing offshore (NCDC, 1986). A similar storm occurred during the period of 13-17 March (NCDC, 1986), with a low pressure cell passing directly over the MBDS area, which also resulted in bottom current velocities on the order of 20-25 cm/sec. Both of these events generated net southerly drift in the near bottom currents, as shown by the 40-HLP data for MBDS (Figure 3.A.2-24).

In summary, the currents at MBDS were characterized by mean tidal current velocities near the surface of 15-20 cm/sec in NNE-SSW orientation which decrease with depth to lower velocity, less periodic currents near the bottom (generally < 10 cm/sec). The wave conditions in the vicinity of MBDS result from both local wind wave formation and propagation of long period waves (swell) generated on the adjoining continental shelf. The most pertinent wave data in the vicinity of MBDS were summarized by Raytheon Company (1974) as shown in Figure 3.A.2-25 and Table 3.A.2-4. The sheltering provided by the coastline severely limits wave generation from the westerly direction; waves from the westerly quadrants larger than 1.8 m (6 ft) occur only 0.5% of the time on an annual basis, and waves over 3.7 m (12 ft) are virtually nonexistent. Conversely, waves from the easterly quadrant that are over 1.8 m (6 ft) occur 4.2% of the time, or nearly ten times more frequently, and waves over 3.7 m (12 ft) occur approximately 0.5% of the year.

Raytheon (1974) also obtained in-situ wave measurements at 42°26'N, 70°43'W, approximately 6 NM west of MBDS during March and April 1974. These data are presented in relation to wind speed in Figure 3.A.2-26.

The importance of the easterly component is also demonstrated by these data; only the easterly wind events associated with 21 and 30 March generate significant waves in excess of 0.5 m, although comparable wind speeds from the northwest occurred from 25 to 28 March. The small, long period waves occurring on 24 and 25 March are characteristic of ocean swell generated at some distance from the site and propagated westward across Massachusetts Bay. The swell condition is demonstrated by the long period (14-16 sec) and low wave height (less than 0.5 m) during periods of low wind velocity (12 mph).

### 3.A.2.c Bathymetry

Massachusetts Bay is bounded on three sides by the Massachusetts coast. On the fourth side, the Bay opens to the Gulf of Maine between Cape Ann and Race Point on Cape Cod. The major topographic features of Stellwagen Basin as shown in Figure 3.A.2-27 (Butman, 1977). The eastern opening is partially blocked by Stellwagen Bank, which rises to within 20 m of the surface. Most of the Bay is less than 80 m deep, although maximum depth in Stellwagen Basin, located in the middle of the Bay immediately west of Stellwagen Bank, is over 100 m (Boehm et al., 1984). The shape of the sea floor is characteristic of an area that has experienced glacial scouring and sediment deposition, as well as post-glacial stream channeling and subsequent modification of bottom contours by advancing post-glacial seas (Padan, 1977).

Bathymetric surveys of the general Massachusetts Bay area including MBDS have been conducted by the National Ocean Survey and plotted on an Outer Continental Shelf Resource Management Map (U.S. Department of Commerce, 1980). Some bathymetric records were made at MBDS as part of a short-term underwater television survey (SubSea Surveyors, 1973). More detailed bathymetric surveys were made at MBDS under the DAMOS program by NUSC (1979). These surveys (Figure 3.A.2-28) indicated a broad depression in the south central region of the site with shoaling in the northeast area toward Stellwagen Bank, and in the north central region toward a smaller feature possibly associated with the bank. None of these surveys were able to discern any topographic features resulting from previous dredged material disposal (NUSC, 1979). Surveys made as part of the 1983 dredged material disposal operations from Boston Harbor also showed no formation of a disposal mound (SAIC, 1985). Bathymetric surveys were also made at a new site, Massachusetts Bay Disposal Site (MBDS) prior to and following parts of the same disposal operation, and results (Figure 3.A.2-29) indicated no significant topographic expression from dredged material at this disposal site (SAIC, 1985).

On 17 and 18 October 1985, a combined side scan and bathymetric survey was conducted at MBDS to define present conditions and to delineate the detectable spread of dredged material previously deposited within the site. Earlier side scan surveys of this general region had been conducted in the past by EPA and NOAA (Lockwood, et al., 1982) and by the New England Division under the DAMOS Program. A secondary objective of the

1985 survey was to compare the present results with the previous surveys and to expand the area of coverage to the east. Earlier surveys concentrated on the disposal site to the west which was used prior to redesignation of the site in 1975.

The results of the bathymetry survey (Figures 3.A.2-30, 3.A.2-31 and 3.A.2-32) show that the topography of the disposal site is characterized by a relatively flat, featureless bottom throughout most of the site with the notable exception of steep shoaling in the northeast and northwest quadrants. The depths throughout the smooth, featureless area are on the order of 85-90 meters, with maximum depths occurring in a broad depression in the south central portion of the site. The shoals in the northeast quadrant, with minimum depths of 57 meters within the site, represent glacially-formed features and are associated with Stellwagen Bank to the east of the site. The smaller shoal in the northwest section of the survey is a small, circular rise which appears to be a single, separate feature, although derived in the same manner as Stellwagen Bank.

There are no significant topographic features related to dredged material disposal; however, acoustic profiles do show indications of more varied microtopography and greater acoustic reflectivity in areas where dredged material may be expected to occur than in areas of natural silt bottom (Figure 3.A.2-33).

#### 3.A.2.d Sedimentology

The sediment composition in Massachusetts Bay as shown in Figure 3.A.2-34 (from Schlee et al., 1973) is dominated by heterogeneous sediments composed primarily of glacial till. This area was glaciated twice during the Ice Age (Willett, 1972; Setlow, 1973). The floor of Massachusetts Bay is characterized by outcroppings of bedrock interspersed with areas of cobble, gravel and sand, with some of the deeper areas grading into fine muds with a high clay content (Willett, 1972; Schlee et al., 1973). Proceeding inshore towards the coastline, spatial variability in grain size increases, with sands dominating along high energy exposed areas and silts and clays within more sheltered embayments. These distributions are interrupted irregularly by glacial till deposits and occasional bedrock outcrops.

MBDS is located within the northwestern corner of the Stellwagen Basin, an area dominated by fine silts and clays. Within the site itself, sediments consist primarily of fine-grained silts and clays with moderate to high concentrations of organic carbon, characteristics representative of deposited dredged materials. Immediately adjacent to the site, mean grain sizes increase slightly with silts dominating distributions along a northwest-southeast trending line extending over distances in excess of 10 nm from the site. Along an east-west trending track, the initial dominance of fines changes to coarser-grained materials ranging to glacial gravels on Stellwagen Bank. Overall, the distributions indicate that MBDS

lies within the depositional basin in the center of the Bay. Martin and Yentsch (1973) reported that sediment samples taken at MBDS were different from those collected at a reference station north of MBDS. Grayish-green mud, characteristic of depths greater than 80 m, was found to be covered with a fine deposit of black mud. This surface layer was absent at the reference station.

Gilbert (1975) described the ocean floor at MBDS as being composed principally of greenish-gray mixtures of fine-grained silt and clay. In the northeast portion of MBDS, the bottom was composed of coarse sand and gravel. Grain size analyses indicated a gradient toward fine-grained sediment in the deeper waters of the site.

Based on surveys made under this program during 1985, the bottom in the general area of MBDS was characterized by four distinct facies. These facies can be characterized according to representative side scan sonar records taken from the locations shown in Figure 3.A.2-35 and presented as Figures 3.A.2-36 to 3.A.2-43, Type 1) Hard sand, cobble and gravel bottoms associated with steep topographic rises (Figure 3.A.2-36), Type 2) Soft smooth sediment with small, high reflectance targets randomly distributed over the bottom (Figure 3.A.2-37), Type 3) High reflectance bottom indicative of dredged material which has specific characteristics including:

A - Extremely coarse dredged material with high reflectance and microtopography on the order of one or two meters as evidenced by shadows (Figure 3.A.2-38),

B - Isolated mounds or deposits of dredged material at some distance from the major areas of accumulations, often consisting of coarse material (Figure 3.A.2-39),

C - Circular high reflectance areas with no relief, frequently adjacent to each other in a consistent linear pattern and sometimes exhibiting crater-like signatures indicative of a specific disposal event (Figures 3.A.2-40 and 3.A.2-42),

D - Dredged material with a stronger reflection than natural sediment but less intensity than that described in 3A and lacking the larger microtopographic features (Figure 3.A.2-42), Type 4) Soft, featureless silty bottoms extending over large areas with occasional trawl marks providing small-scale topographic relief (Figure 3.A.2-43).

Additional information on the characteristics of sediment at MBDS was obtained through photography of the sediment-water interface using a REMOTS camera. The grain size of sediments measured by REMOTS indicated that a sharp gradient existed between those stations in the northeast quadrant and those located in the rest of the site.

Those to the north and east consist of coarser sediments ranging from very fine sand (4 - 30) to gravel (0 to -10). Sediments at these coarse bottom stations are generally poorly sorted, with fine to medium sand lying over coarser material. There are relict bedforms in this area, apparently stabilized by dense mats of polychaete tubes (Figure 3.A.2-44). The construction of dense polychaete tube fields may have caused the sedimentation and retention of fine-grained particles. The remainder of the site, in deeper areas to the south and west, is characterized by fine silt sediments shown in Figure 3.A.2-45 and deposits of dredged material. The presence of dredged material is indicated in REMOTS images by the following features: sand layers in an otherwise homogeneous mud facies, the presence of buried mud clasts, mottled sedimentary fabrics, the presence of "relict" (i.e. buried) redox layers (Figure 3.A.2-46). It is important to note that the REMOTS technique is capable of detecting dredged material for a longer period of time after disposal than side scan sonar. The primary reason for this is that the sediment surface returns to a natural condition in terms of acoustic reflectivity long before the sediment beneath the surface is fully oxidized.

The results of the bathymetric, side scan and REMOTS survey were used to select sample locations to characterize the sediment facies present in the MBDS area. The sample locations are presented in Figure 3.A.2-47 and the results of the grain size analysis are presented in Table 3.A.2-5. Samples were taken at the "MUD" reference station during June and September, 1985 and February, 1986 and all indicated very little variation with the mean grain size indicative of a fine silt, averaging 0.013 mm (60). In nearly all samples from the reference station more than 95% of the sample, by weight, was material of silt size or finer. When these deposits are compared with natural mud samples from within the disposal site (Table 3.A.2-5), the sediments are virtually identical. Thus, in terms of the sedimentation parameters, the reference station is a good representation of the disposal site.

A "SAND" reference station was also established outside the boundaries of MBDS to establish a control for measurements in the northeast quadrant of MBDS, where a natural sand station was also established. Although these stations showed much more variability, they were similar in composition with 94% of the sediment, by weight, representing sand or larger material. The mean grain size for the Sand Reference Station was 2.71 mm (-10) and for the Sand Station was 1.24 mm (00).

Samples obtained from the dredged material deposited at the site were predominantly fine sand and silt with a mean grain size of 0.065 mm (40) and slightly more variability than the natural sediment. In particular, the dredged material contained more sand sized particles than natural sediment.

A substantial amount of information concerning the characteristics of the disposal site, the distribution of sediment types and the effect of previous disposal operations can be determined from the data presented in

the previous sections. An overview of the sediment characteristics at MBDS, combining the results of all survey procedures, is presented in Figure 3.A.2-48.

Of the two types of natural bottoms, the Type 1 areas (hard sand) are located in the northeast portions of MBDS, where the sandy bottom is related to the shoaling topography approaching the Stellwagen Bank. To the northwest beyond the margins of the site, the sand and coarse sediment are associated with an isolated topographic feature which appears to be a relict glacial formation created in the same manner as the Bank.

The soft, featureless silty bottoms are found extensively throughout the southeastern portion of the study area and are the predominant natural bottom throughout the region of the disposal site. The dredged material and other targets are deposited on top of this natural sediment.

In the northwest quadrant of the disposal site, extending to the west of the study area, the bottom is covered by small targets which have been identified through underwater television to be canisters and drums deposited on the bottom. It is known that both chemical and low level radioactive wastes have been deposited at the site in the past either in cement canisters or 55 gallon drums (Lockwood et al., 1982). However, it is impossible to determine which targets represent which type of waste from the side scan record. The previous surveys by NOAA and EPA indicate that these targets are generally concentrated west of the existing disposal site (Figure 3.A.2-49), although it is highly probable that many canisters or drums are covered with dredged material in the west central portion of the site.

The dredged material detected by sidescan sonar is generally concentrated in the vicinity of the disposal buoy placed by the Coast Guard at 42°25.66'N, 70°35'W, although it has spread over a relatively large area. The major disposal projects at this site during the past several years have been associated with dredging of the Chelsea and Mystic Rivers in Boston Harbor and President Roads at the entrance to the harbor. During 1983, all of the material from the rivers was dredged by clamshell techniques and deposited east of the Coast Guard Buoy by scows towed by tugs. Material from President Roads was partially dredged by clamshell and deposited by scows at a taut-wire mooring, located at 42°25.39'N, 70°34.54'W, approximately 850 m southeast of the Coast Guard Buoy. The remainder of President Roads was dredged by a hopper dredge and deposited at the same location under Loran-C control.

Examining the distribution of dredged material, it is apparent that the high reflectance material with microtopographic features is concentrated in the vicinity of the disposal buoy and extends westerly into the historically used site located just west of the existing disposal site. Progressing to the south, the intensity of the dredged material signature decays, although the sediment present has substantially more reflectance than the natural bottom. To the north, the boundary between the coarse

dredged material and natural bottom is much more pronounced, and material is seen as isolated deposits of coarse material or as the circular deposits with relatively high reflectance.

The area to the west of the existing disposal area also exhibits evidence of dredged material and falls within the boundaries of the historical disposal site adjacent to the present site. REMOTS images from that area revealed no evidence of recent disposal activity (i.e. within the last six months) at any of those stations. The material observed appeared to represent relict sediments from past disposal activities (greater than 5 cm below the sediment-water interface).

Figures 3.A.2-50 and 51 present the distribution and thickness of dredged material at MBDS as measured by REMOTS photography used to generate the map of sediment types presented in Figure 3.A.2-48. It is apparent that the dredged material deposited prior to this study has remained in place and that there are very few forces acting on that material since it still retains its distinct signature more than two years after disposal.

The dredged material distribution is generally explained by the procedures used in disposal at the site. During the clamshell and scow operations, the tug operators would approach the buoy from the northwest, swing to the east, and dump material as they or the scow passed the buoy. Consequently, there were few dumps to the north, but when they did occur they can now be seen as distinct entities on the side scan record. Coarse dredged material observed as much as 1000 m to the north of the buoy indicates that careful control of disposal was not exercised during the initial disposal operation. As the scow passed the buoy, most of the material was deposited; however, not all of the material may have fallen from the scow at once, and because the tug was moving in a southerly direction, the tendency was for some material to be deposited to the south.

The effect of disposal control was further emphasized when the location of the disposal point was moved to the southeast during the President Roads operation. Installation of a taut-wire moored buoy for control of scow operations and use of Loran-C navigation for hopper dredge disposal were two methods implemented to increase the precision of disposal. The distribution of dredged material resulting from that operation covered a substantially smaller area than previous projects (Morton, 1984) and it was apparent that better control of disposal would be necessary to properly manage future projects.

A third disposal point was established in November 1985 at 42°25.1'N, 70°34.45'W and a taut wire buoy was installed at that location for disposal operations during the winter. During February 1986, REMOTS photographs were obtained at the stations established during the 1985 surveys and at 26 stations spaced at 100 m intervals on a cross centered at the new disposal point. The results of the analysis of these photographs are presented in Figure 3.A.2-52 and 3.A.2-53.

The dredged material (approximately 197,000 m<sup>3</sup>) deposited during this period covers approximately 400 meters in all directions. To the north, the dredged material apparently overlaps with sediments from past disposal activity. To the west, apparent patches of dredged material are evident as far as 600 meters from the center of the site. Also, at station 250SW (i.e. grid station 16-9), a thick layer of dredged material is evident (greater than 17 cm). The lateral spread of dredged material extending from the disposal buoy was comparable to disposal mounds created in Long Island Sound (i.e. approximately 400-500 meter radius). A recent REMOTS survey at the same disposal point, following the addition of approximately 94,000 m<sup>3</sup> of dredged material has further delineated the spread of dredged material and verified the stability of these deposits. The REMOTS images obtained in January, 1987, at the same stations as occupied during the February 1986 survey indicating virtually the same spread of dredged material (Figure 3.A.2-54). In the center of the survey area, near the disposal buoy, two areas of recently deposited dredged material were identified through the presence of a shallow Biogenic Mixing Depth (BMD) and extremely dark reduced sediment. From these data it is apparent that disposal of the new dredged material has been tightly controlled and the effects of disposal have not been expanded beyond the area originally covered.

In summary, the bottom in the deeper portions of MBDS is a broad depression with natural sediments composed of fine grained silt. Shoal areas to the north and northeast are covered by coarser deposits. Dredged material previously deposited in the site is spread over a relatively large area, but has not been altered or transported to any significant degree during the past several years. Recent disposal operations have shown that with adequate navigation, the spread of material on the bottom is approximately similar to that which would be expected in more shallow water.



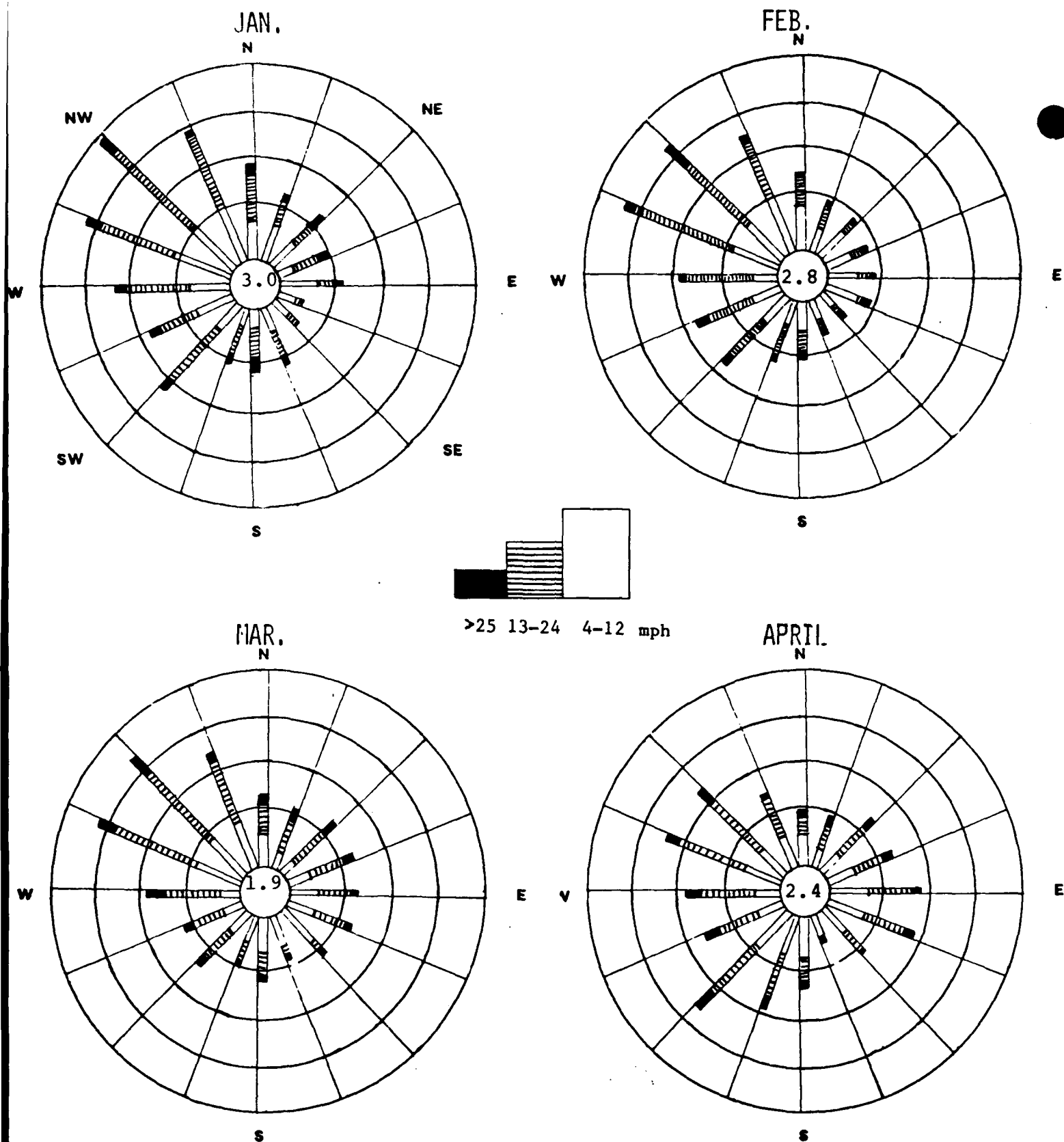
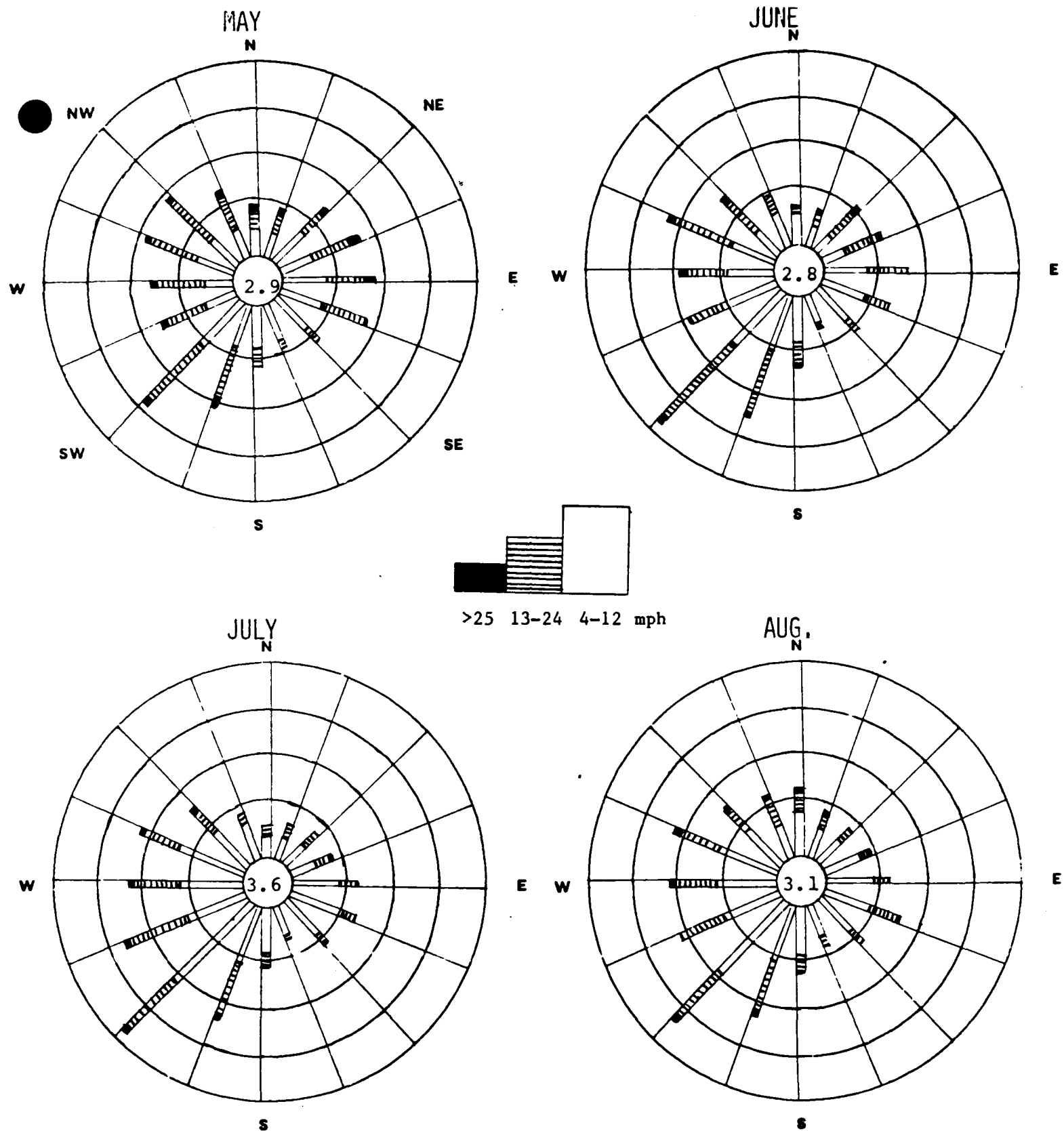
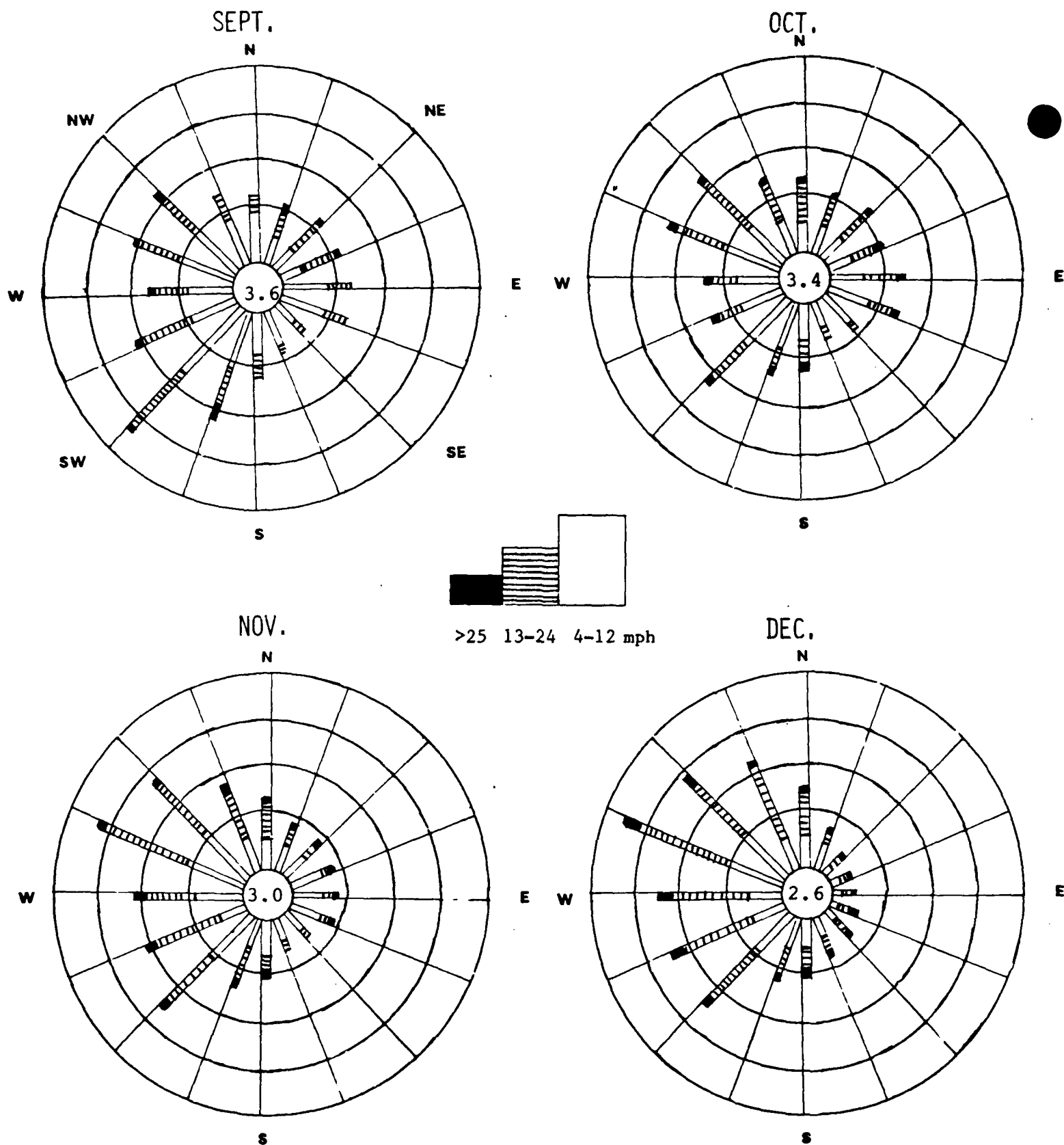


Figure 3.A.1-1a Fifteen year (1950-64) monthly averaged wind roses, Boston, MA. Center circle = % calm, concentric circles = 4, 8, 12 & 16% (from Metcalf & Eddy, 1984)

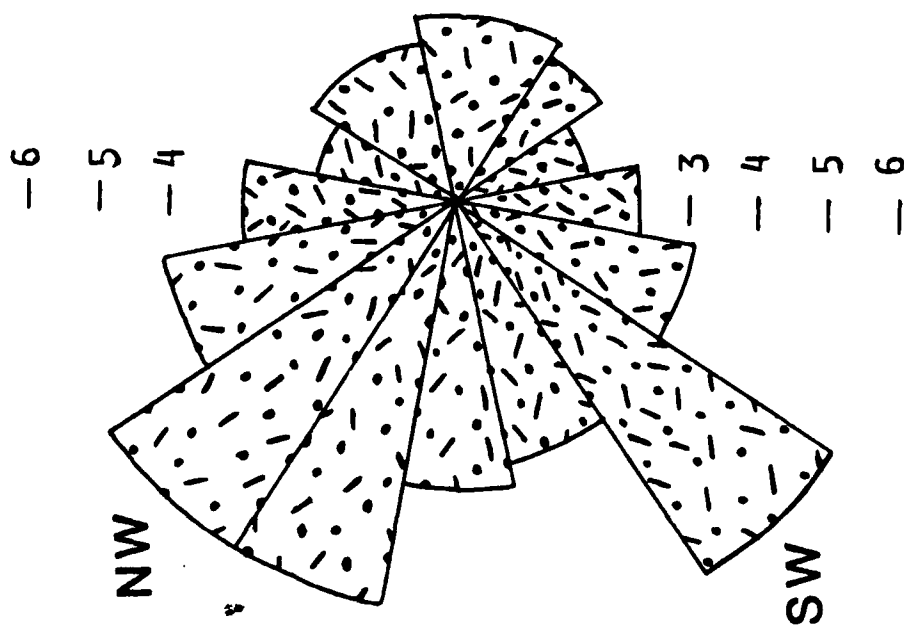


**Figure 3.A.1+1b** Fifteen year (1950-64) monthly averaged wind roses, Boston, MA. Center circle = % calm. concentric circles = 4, 8, 12 & 16% (from Metcalf & Eddy, 1984)



**Figure 3.A.1-1c** Fifteen year (1950-64) monthly averaged wind roses, Boston, MA. Center circle = % calm, concentric circles = 4, 8, 12 & 16% (from Metcalf & Eddy, 1984)

% DURATION PER YEAR



% DURATION PER YEAR

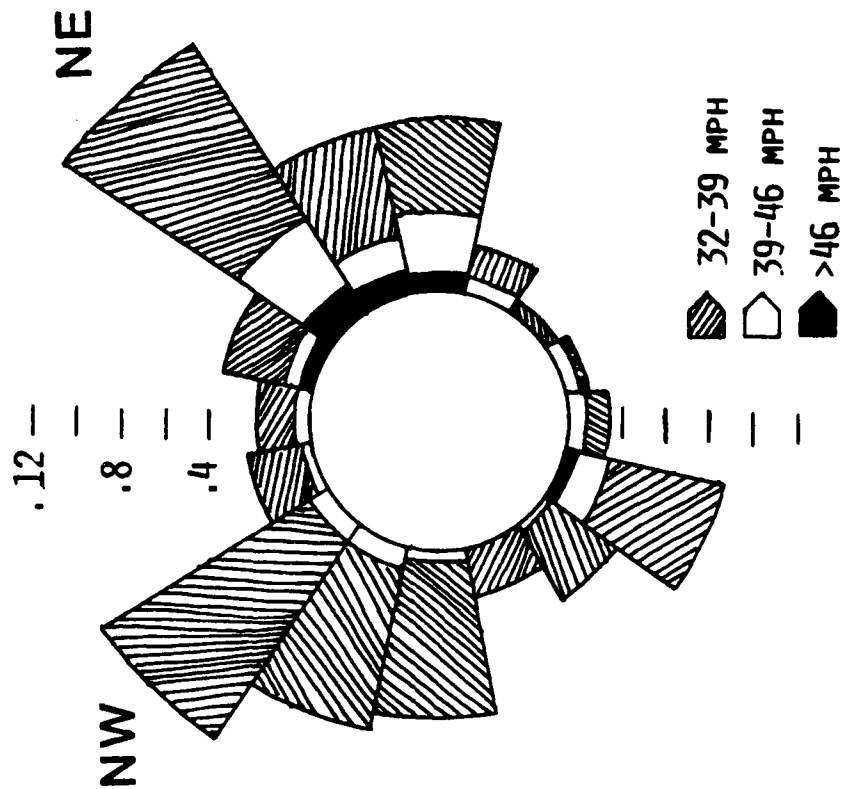


Figure 3.A.1-2 Characterization of Massachusetts Bay wind conditions (from Hayes, Hubbard & Fitzgerald, 1973)

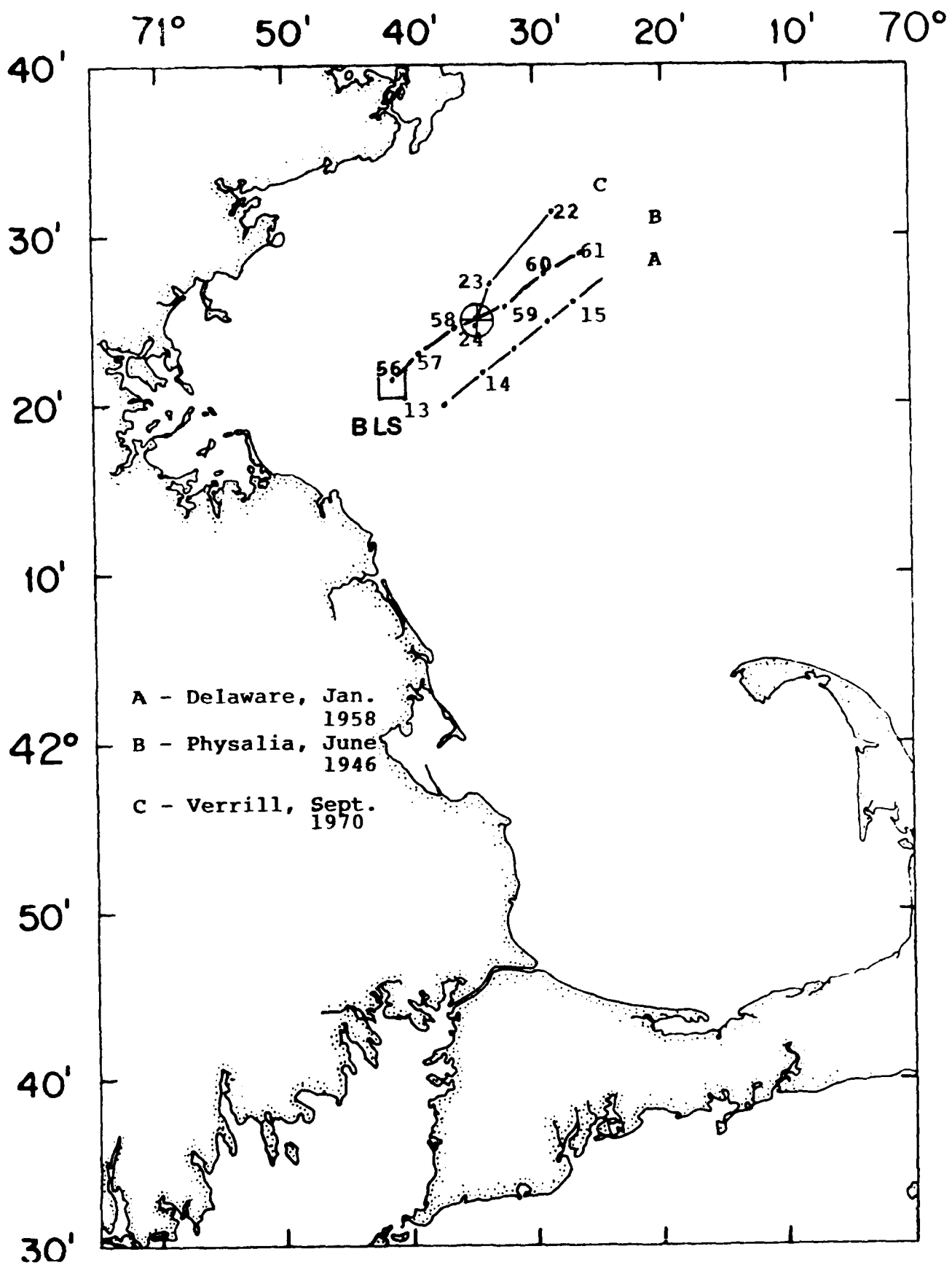
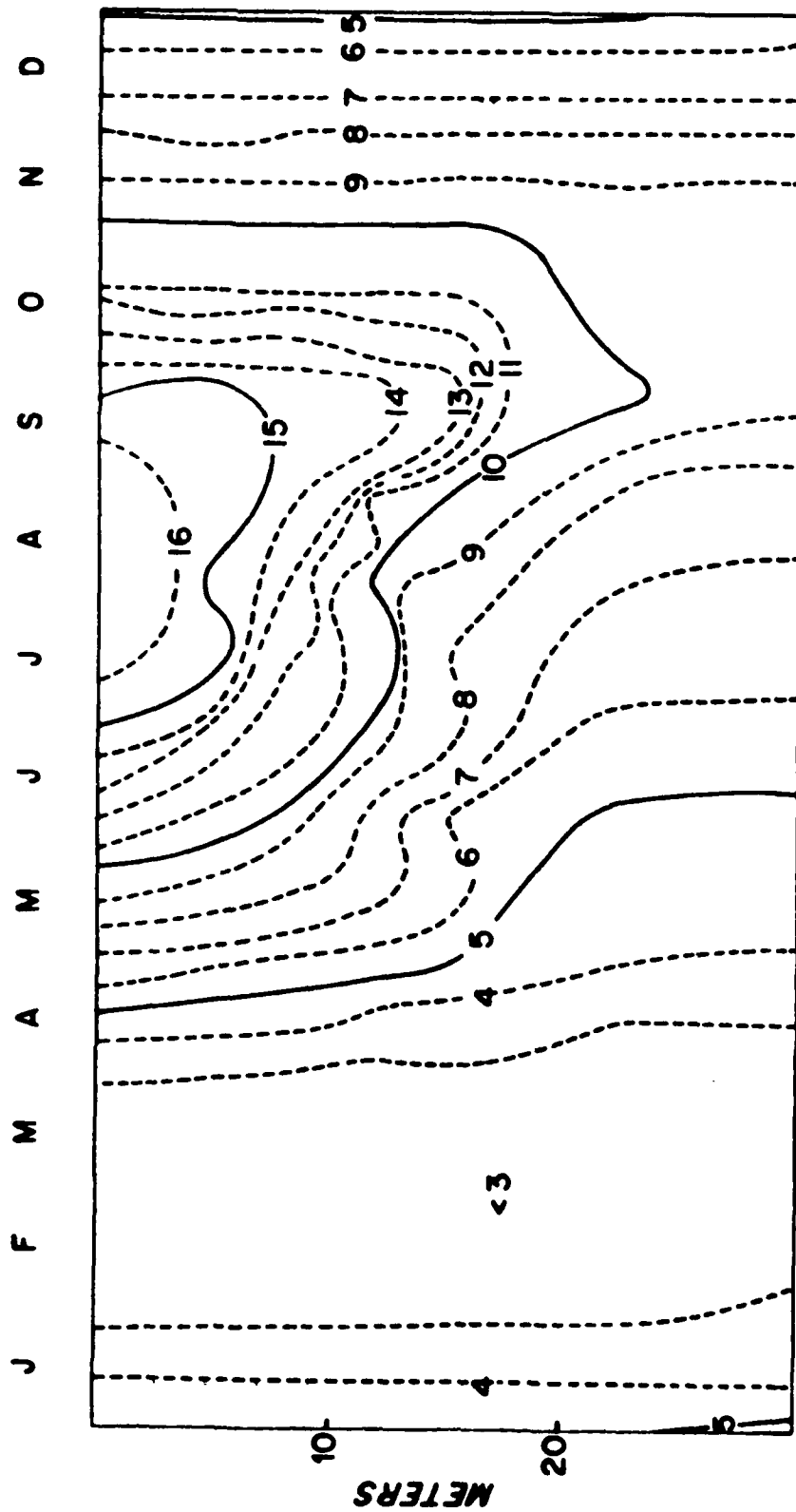


Figure 3.A.2-1 Location of temperature transects in the vicinity of MBDS (Bumpus, 1974)



**Figure 3.A.2-2** Profile of mean annual temperature ( $^{\circ}\text{C}$ ) cycle at Boston Lightship, southwest of MBDS (from Bumpus, 1974)

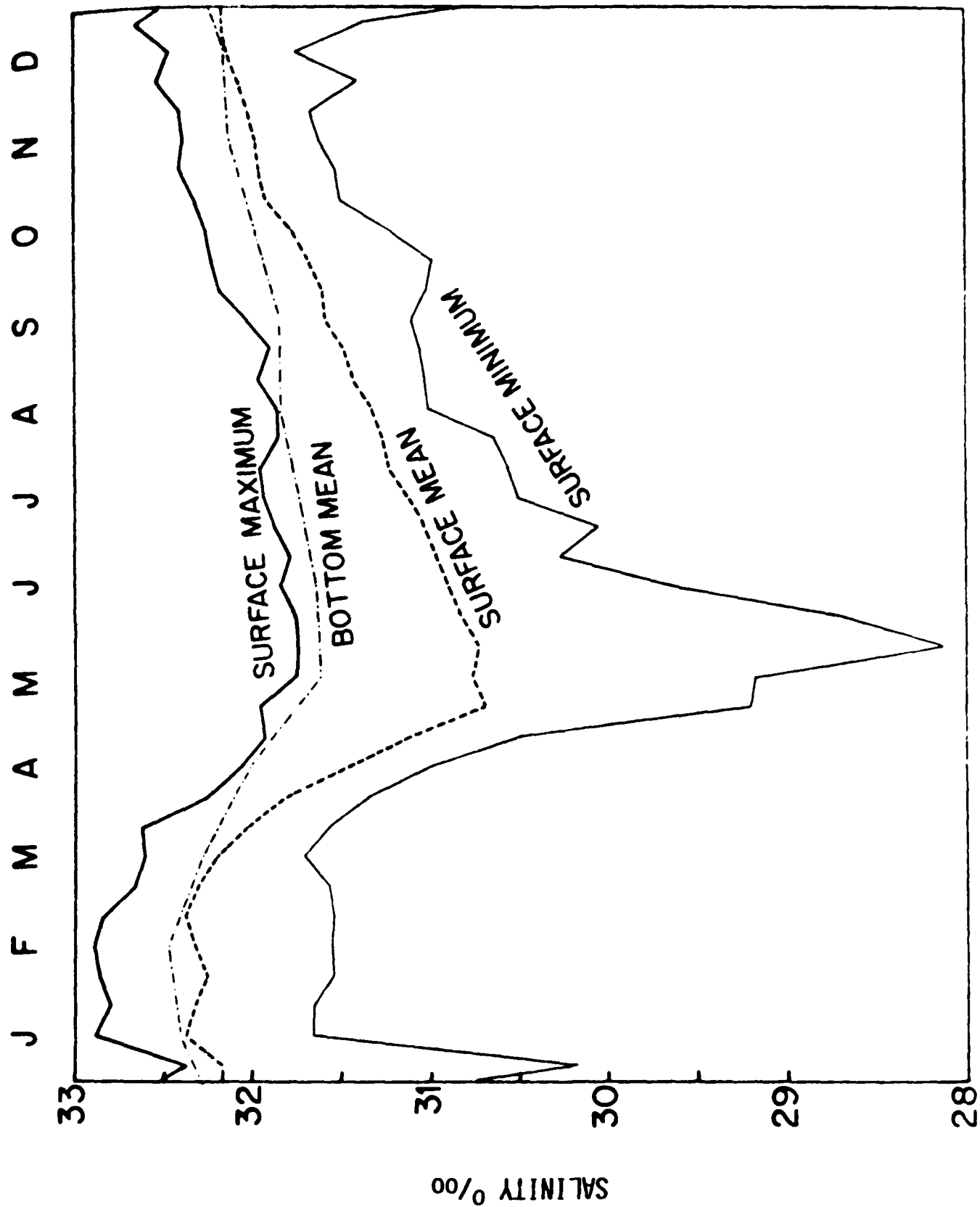
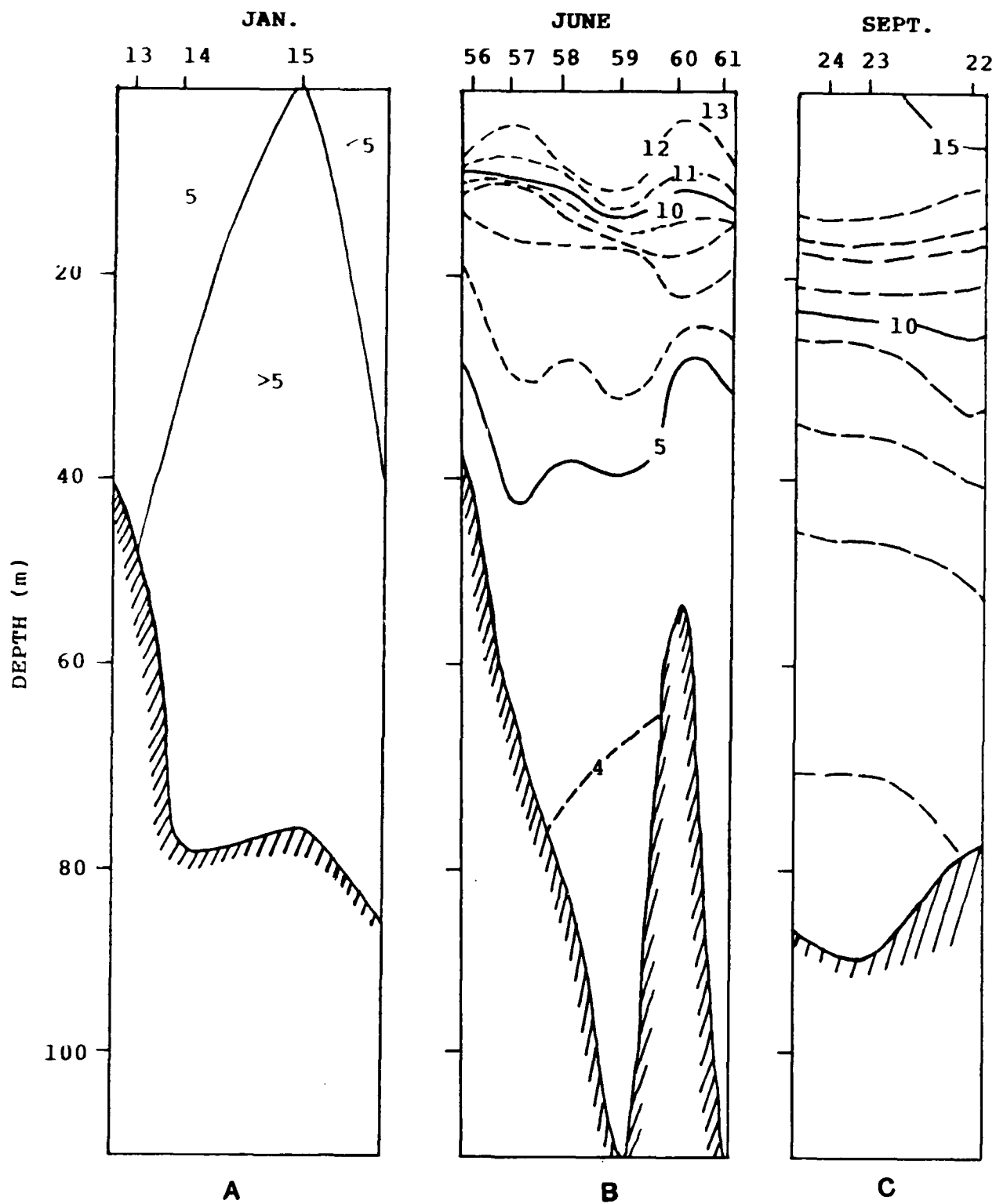
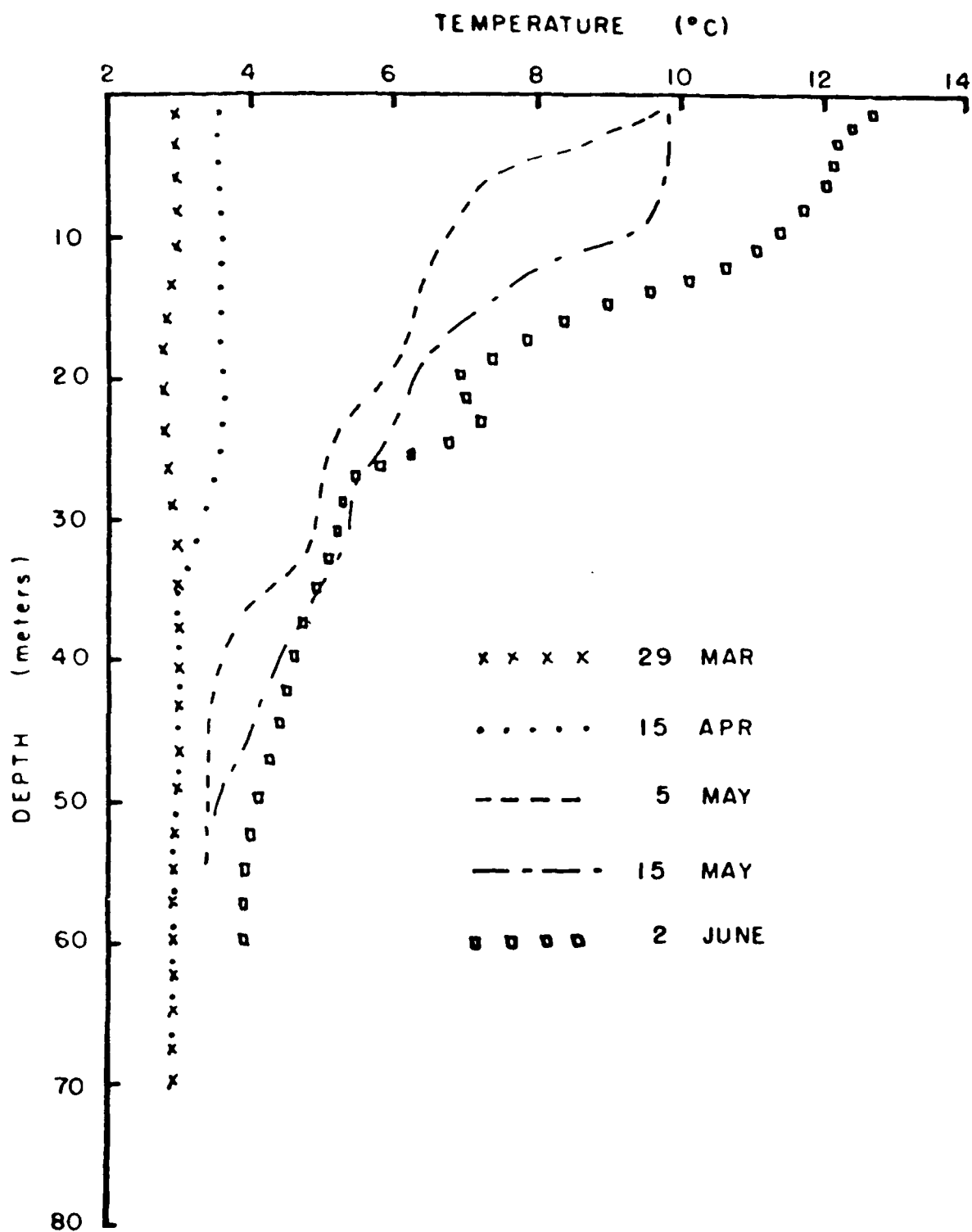


Figure 3.A.2-3 Annual cycle of salinity (o/oo) at Boston Lightship, southwest of MBDS (from Bumpus, 1974)



**Figure 3.A.2-4** Temperature ( $^{\circ}\text{C}$ ) transects in the vicinity of MBDS (from Bumpus, 1974)





**Figure 3.A.2-5** Vertical profiles of temperature (March - June, 1973) (from Butman, 1977)

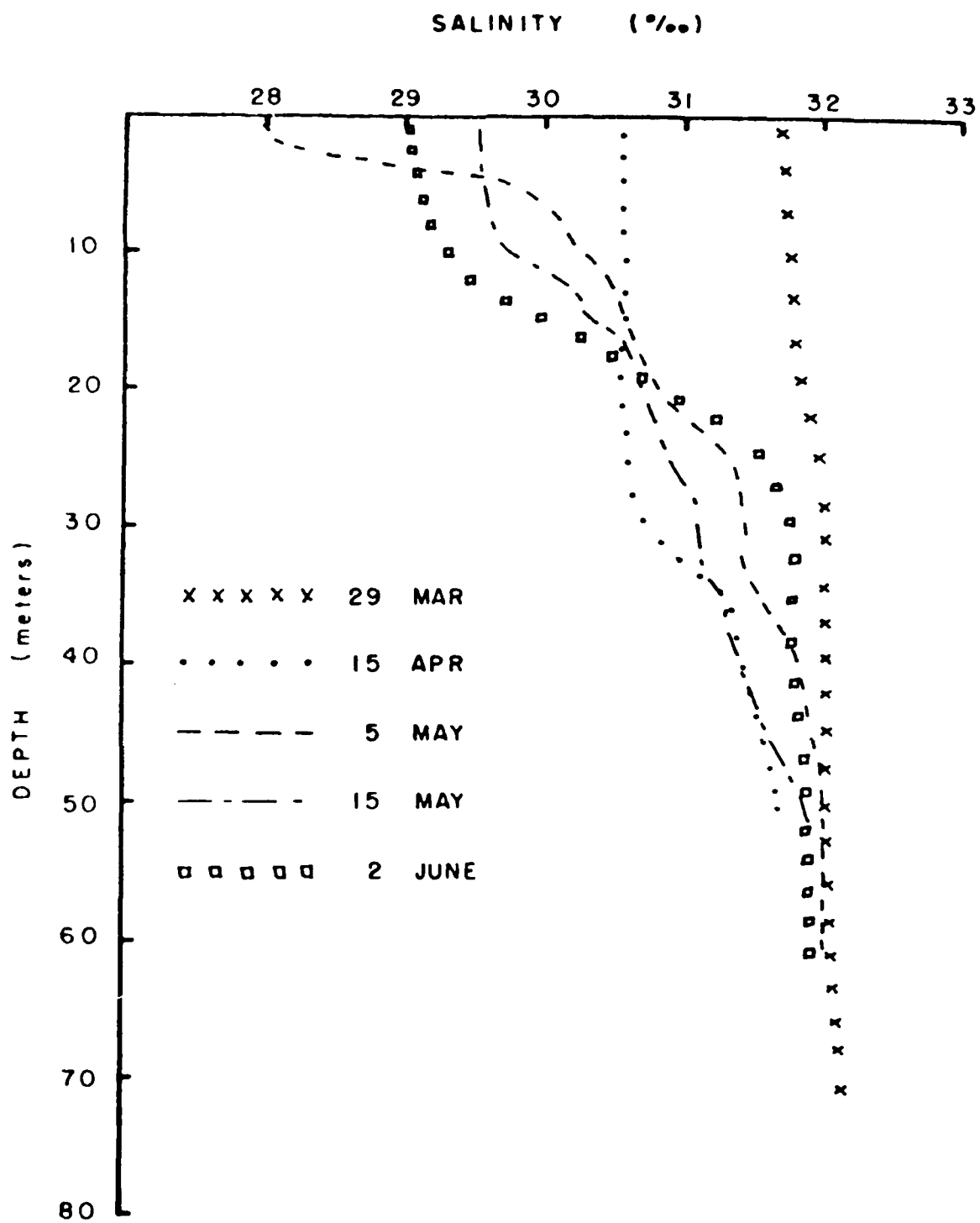


Figure 3.A.2.6 Vertical profiles of salinity (March - June, 1973)  
(from Butman, 1977)

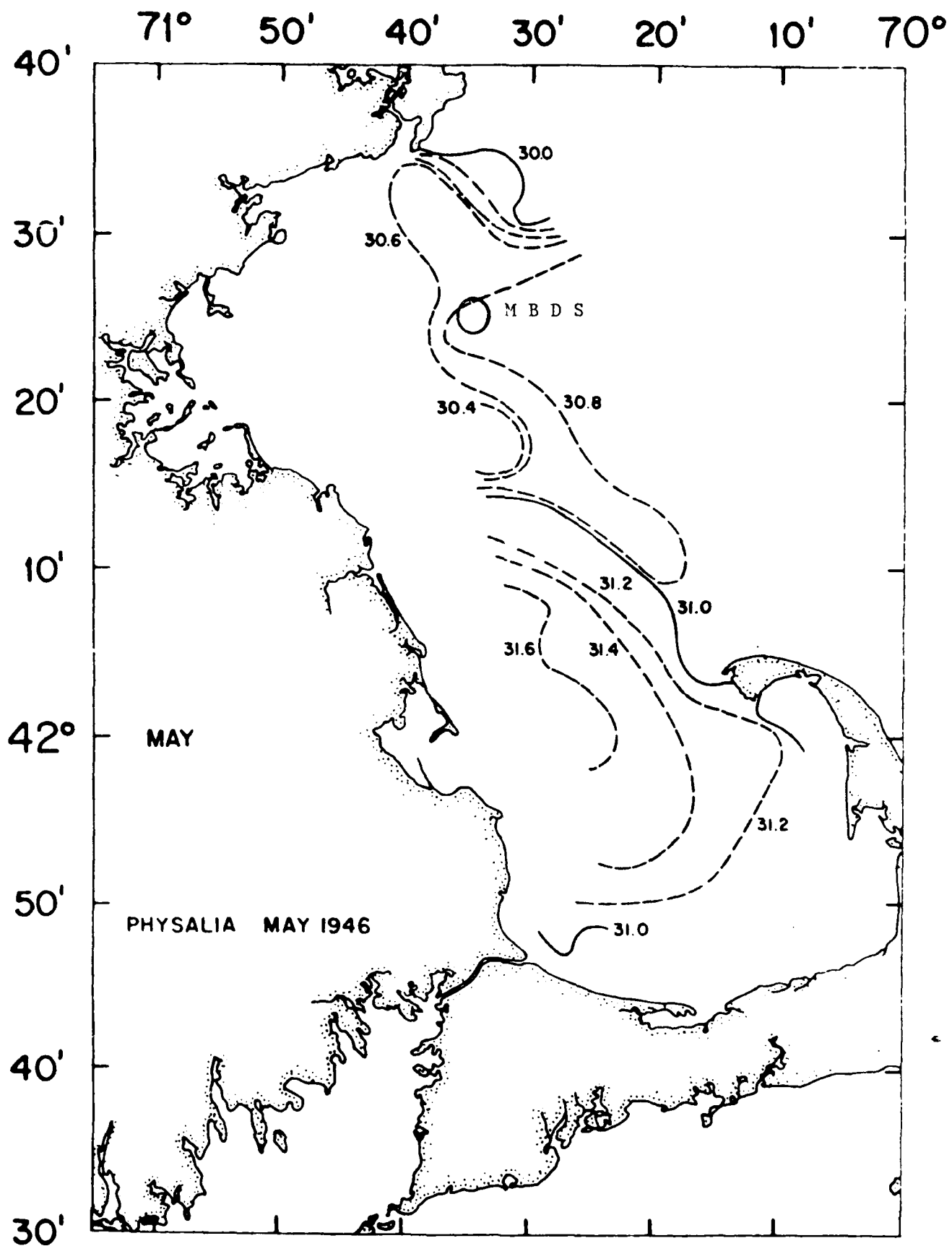


Figure 3.A.2-7 Surface salinity (o/oo) in May, 1946 (from Bumpus, 1974)

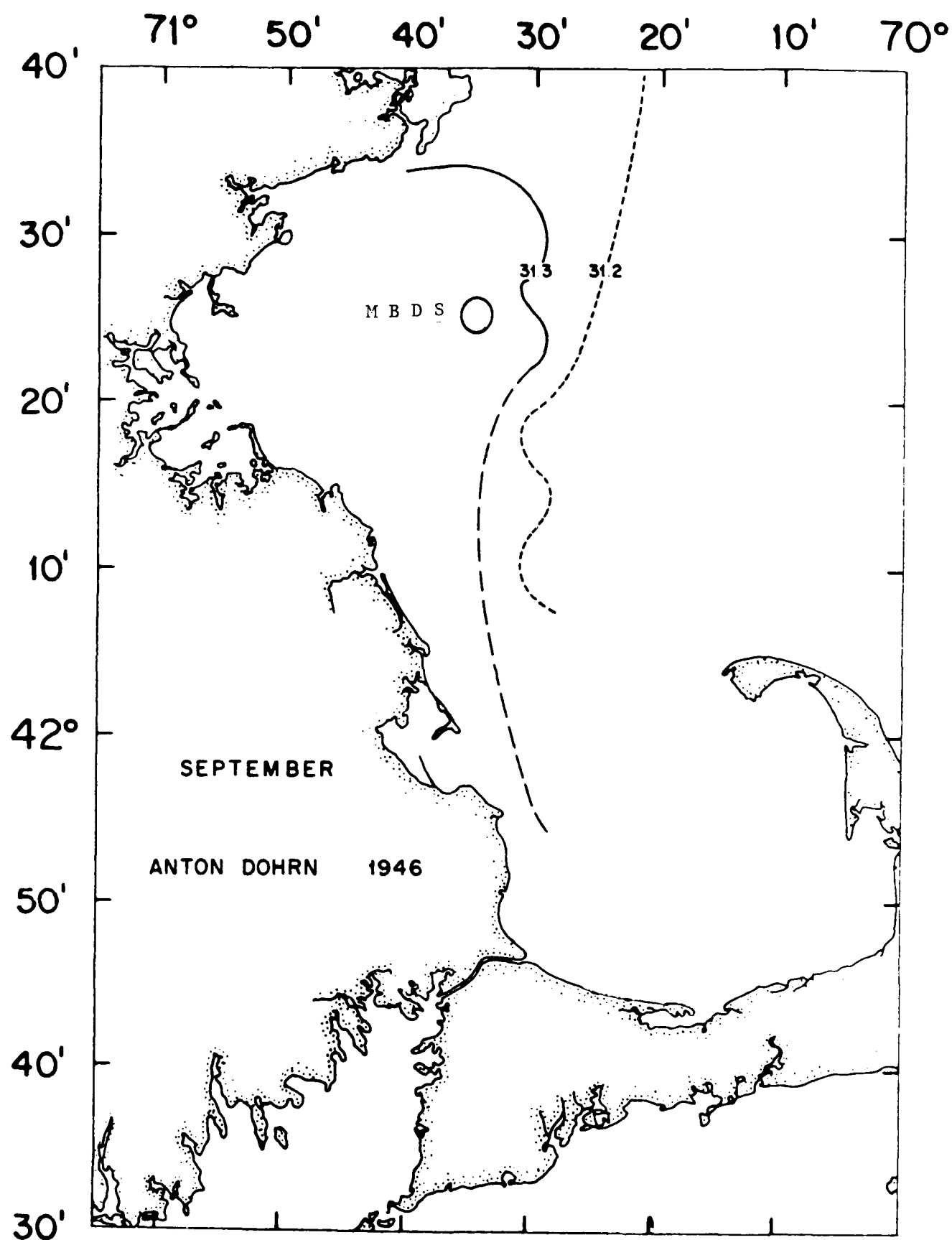


Figure 3.A.2-8 Surface salinity (o/oo) in September, 1946 (from Bumpus, 1974)

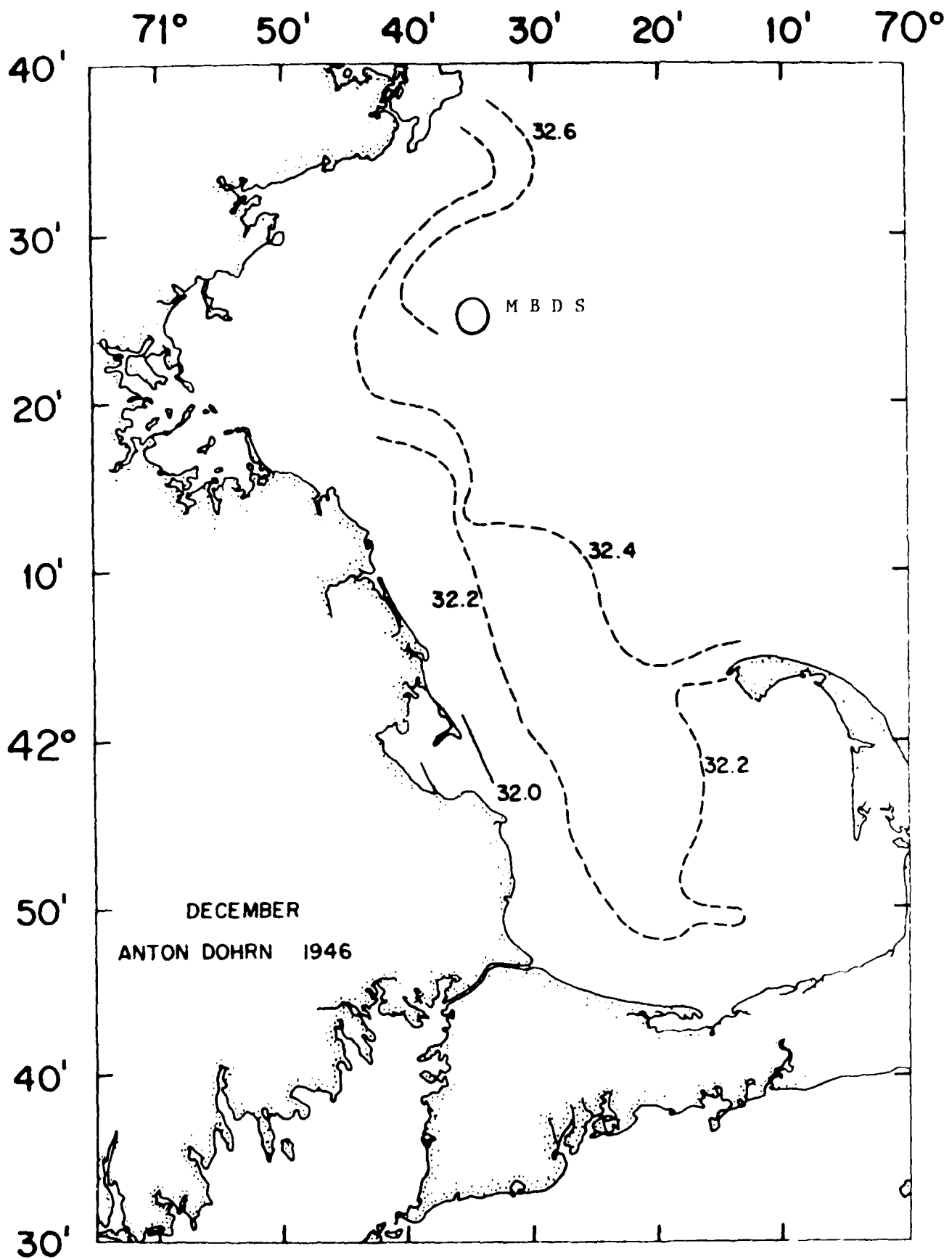


Figure 3.A.2-9 Surface salinity (o/oo) in mid-December, 1946  
(from Bumpus, 1974)

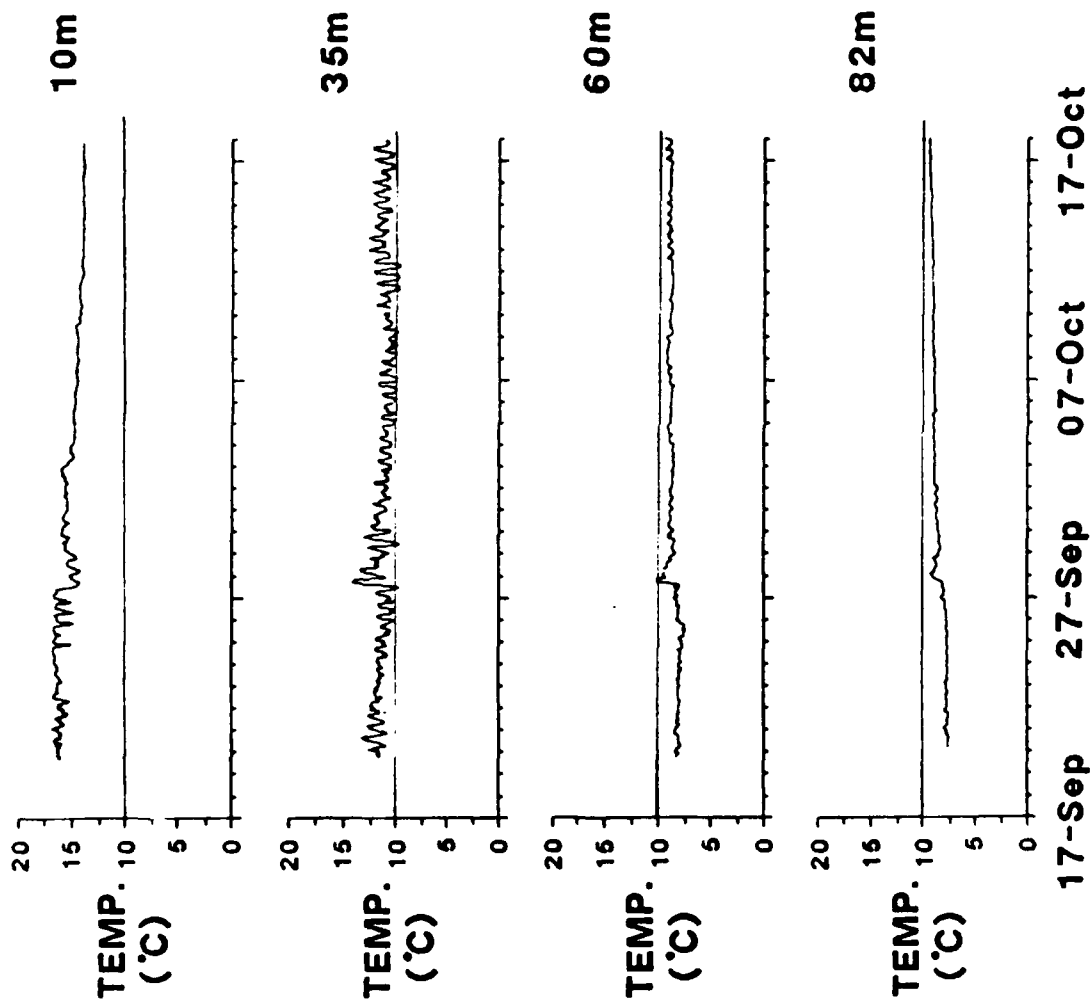
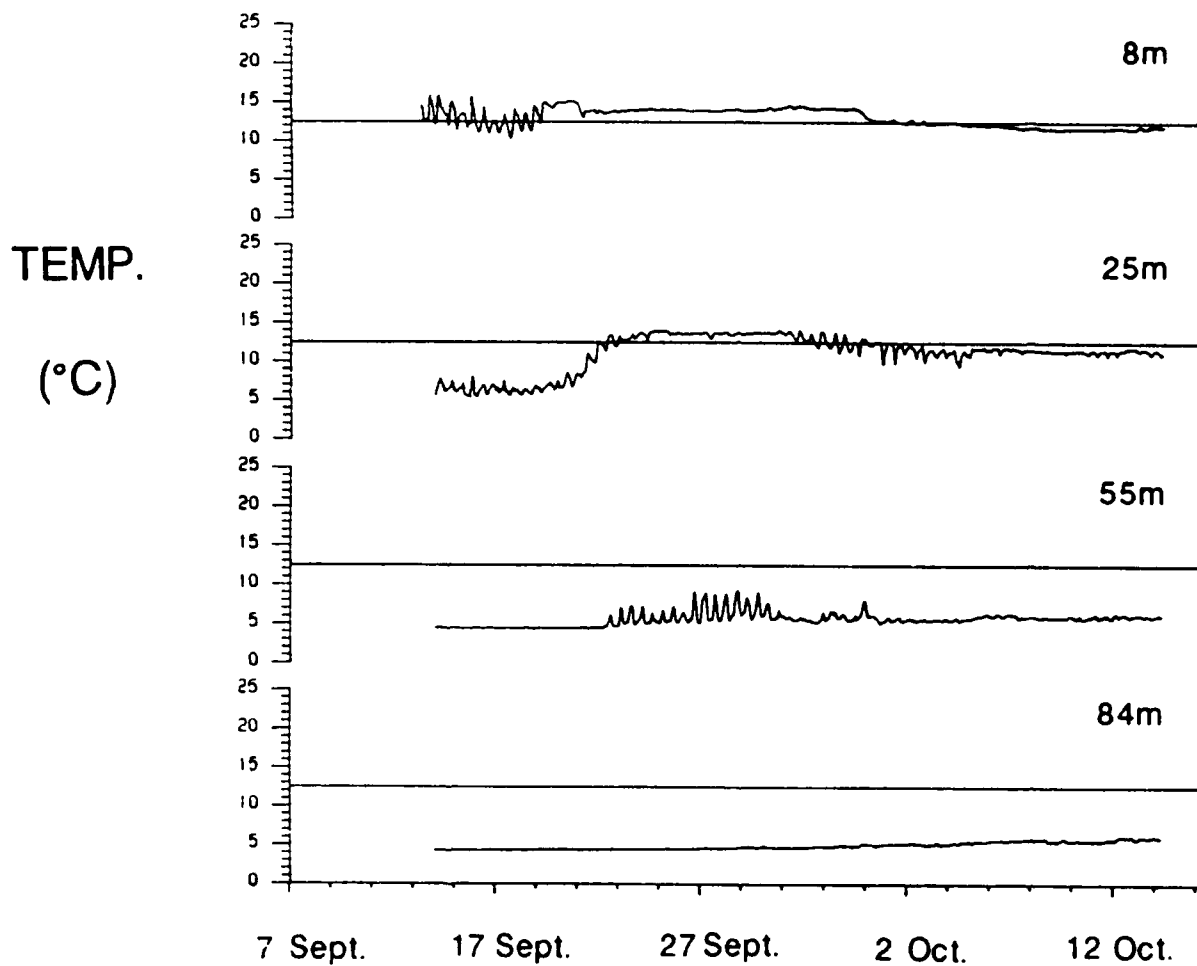
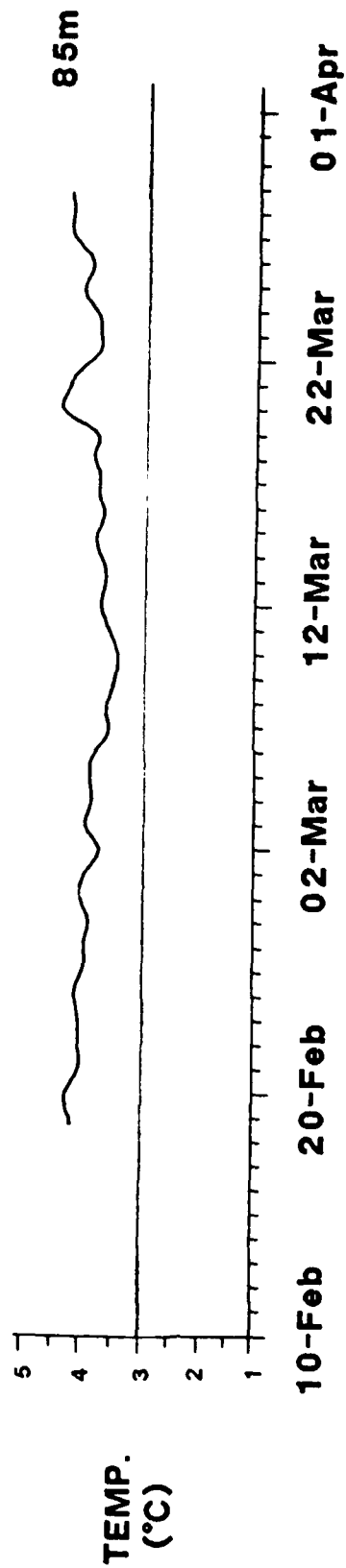


Figure 3.A.2-10a Time series of temperature (°C) measured at four depths at  
MEDS (20 Sept. - 18 Oct. 1985)



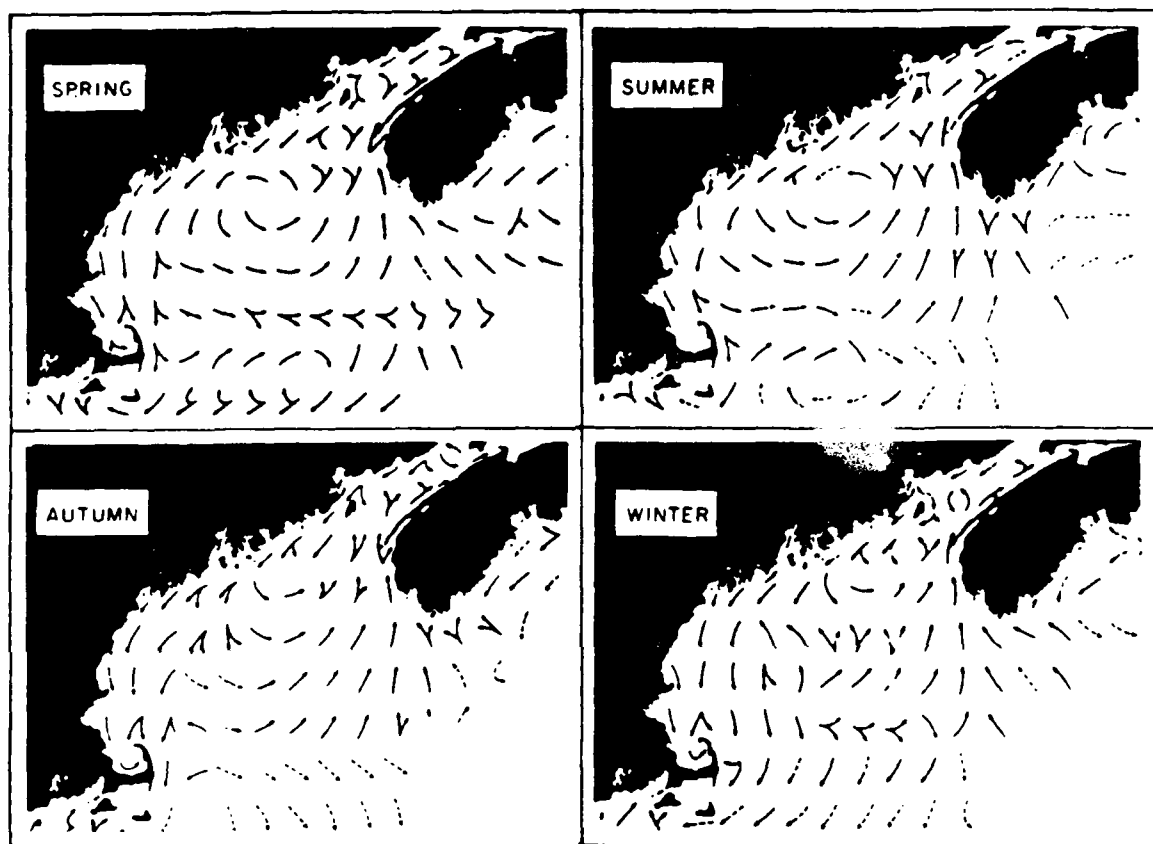
**Figure 3.A.2-101: Time series of temperature (°C) measured at four depths at MBDS (12 Sept. - 19 Oct. 1987)**



**Figure 3.A.2-11** Time series of near-bottom (85 m) temperature (°C) measured at MBDS (19 Feb - 30 March, 1986)







**Figure 3.A.2-13** The seasonal variation of circulation in the Gulf of Maine. The characteristic counterclockwise current is well developed near the center of the Gulf in spring. As the year progresses, the center of the gyre tends to move northward as the driving forces weaken and the current becomes more diffuse (from Bumpus & Lauzier, 1965).

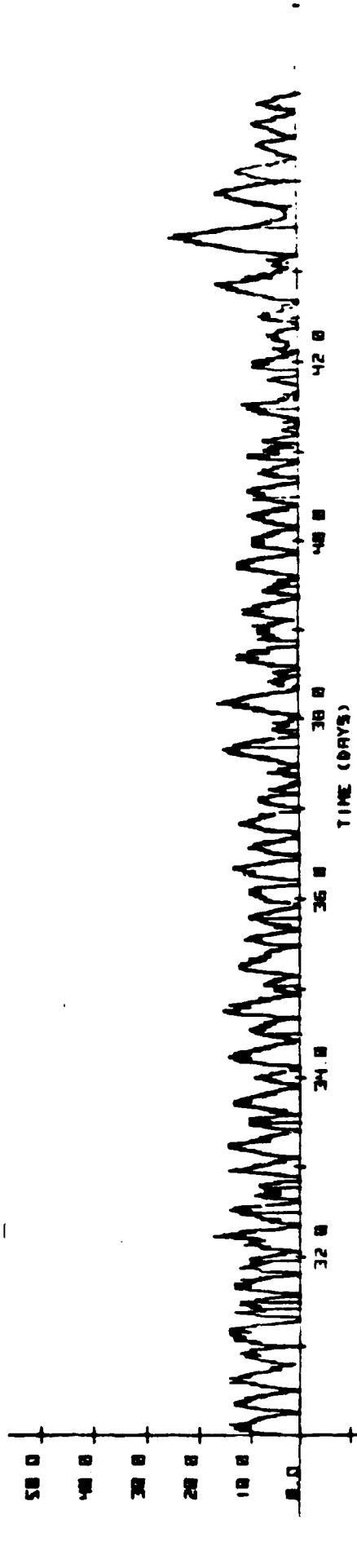
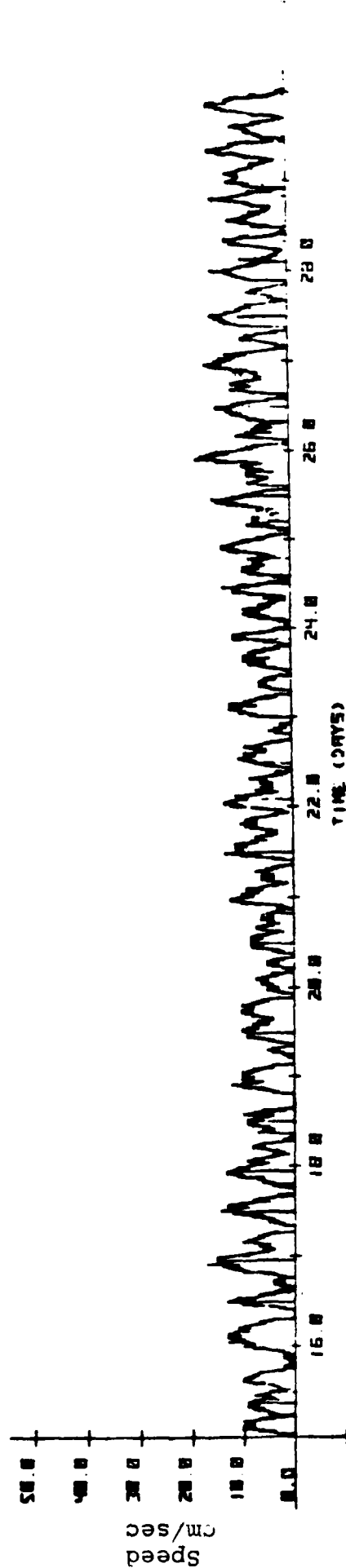
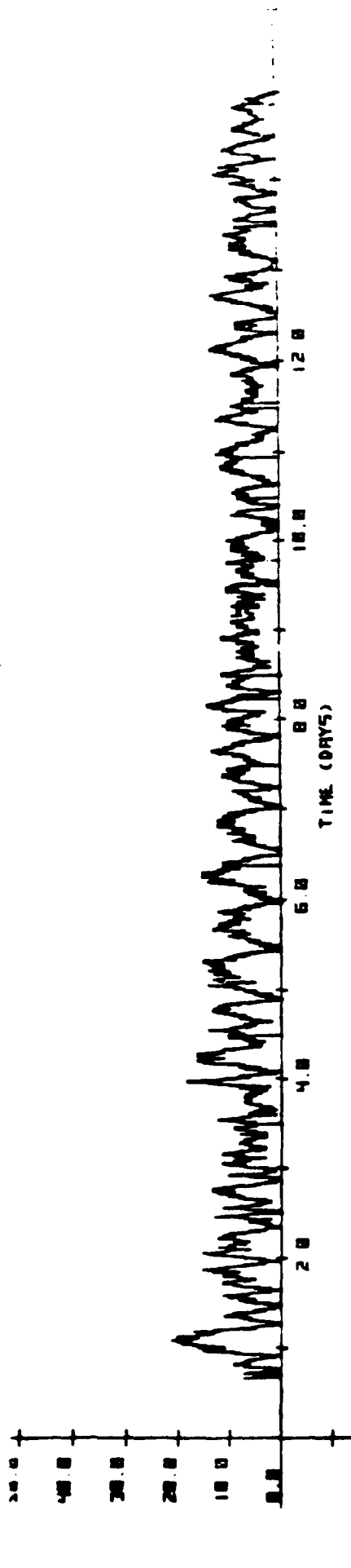
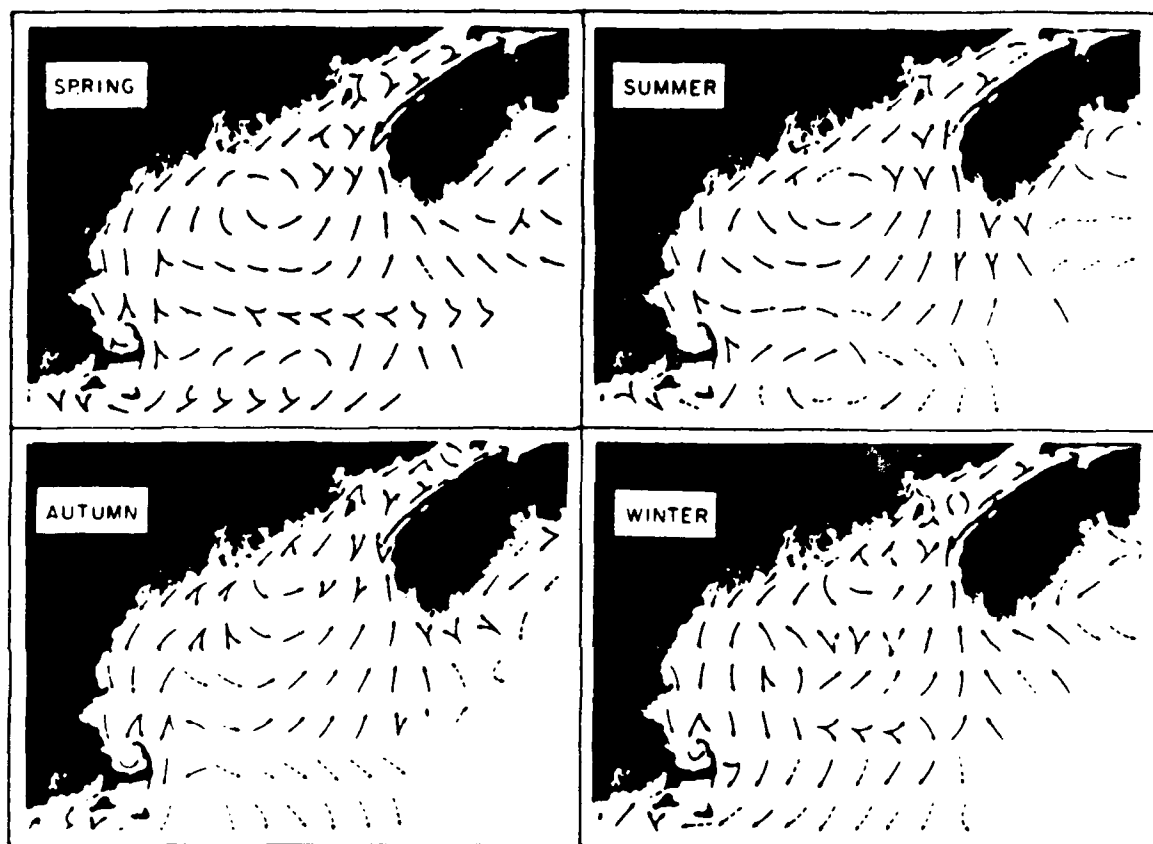


Figure 3.A.2-14 Time series of near-bottom current speed (cm/sec)  
at MBDS (23 May - 10 July, 1978) (from NUSC, 1979)



**Figure 3.A.2-13** The seasonal variation of circulation in the Gulf of Maine. The characteristic counterclockwise current is well developed near the center of the Gulf in spring. As the year progresses, the center of the gyre tends to move northward as the driving forces weaken and the current becomes more diffuse (from Bumpus & Lauzier, 1965).

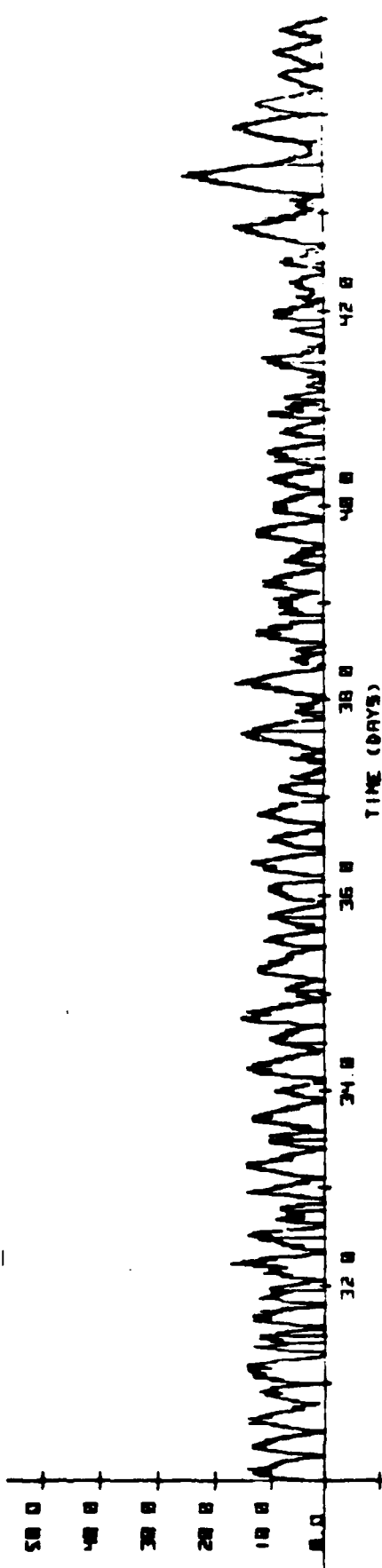
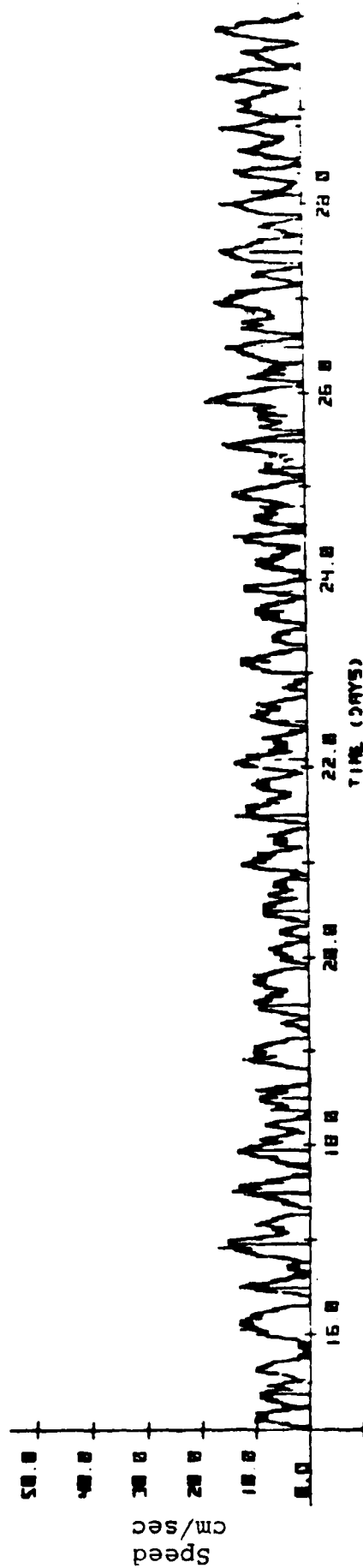
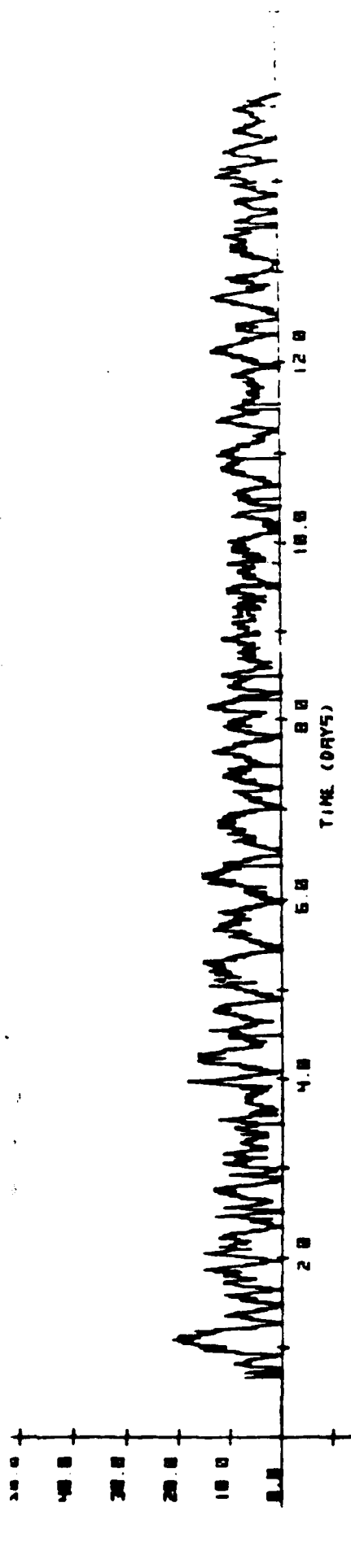


Figure 3.A.2-14 Time series of near-bottom current speed (cm/sec)  
at MBDS (23 May - 10 July, 1978) (from NUSC, 1979)

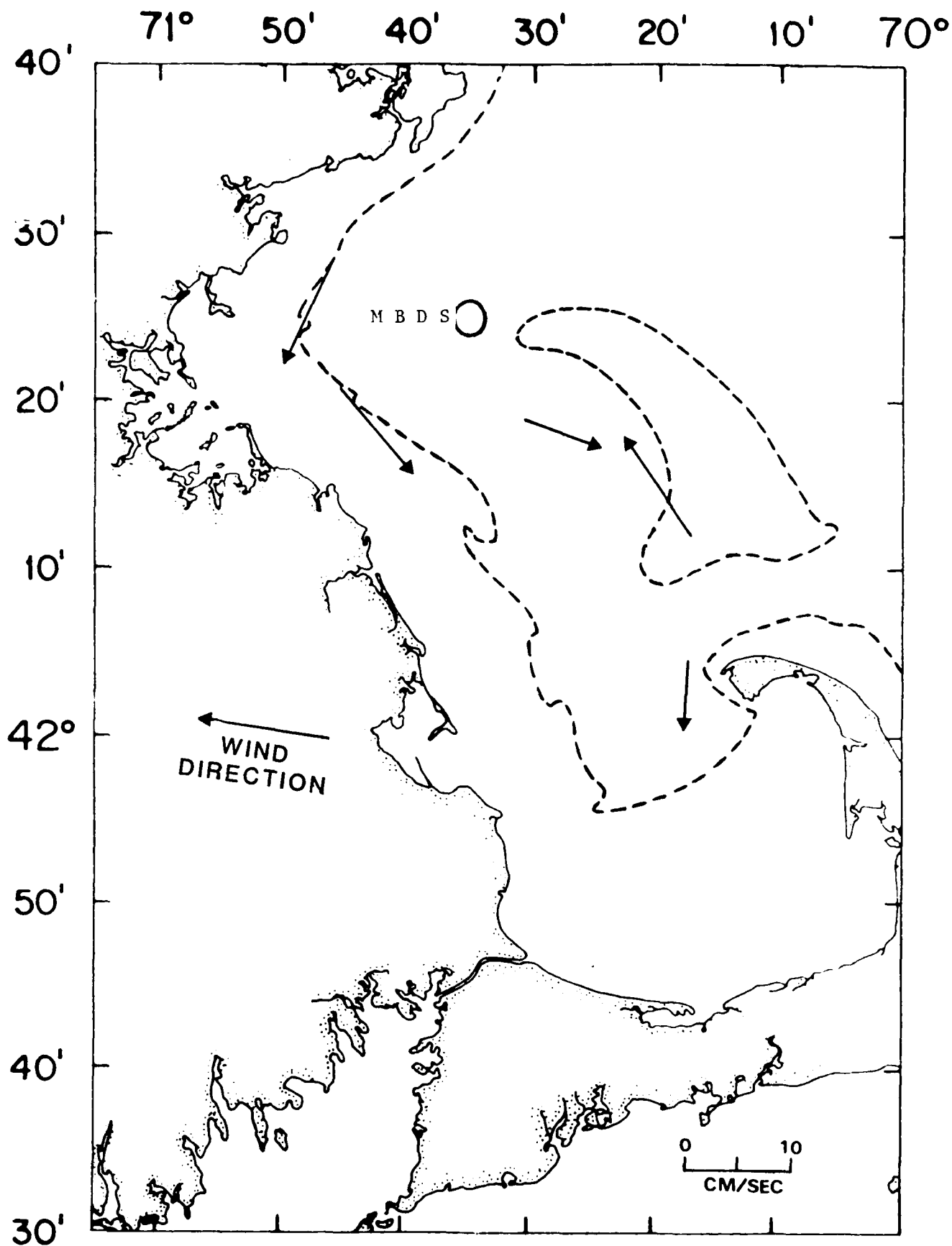


Figure 3.A.2-15 Generalized response of bottom currents to strong easterly wind conditions at MBDS. Vectors were constructed from measurements made at different times, but under similar wind conditions during the winter months (from Butman, 1977)

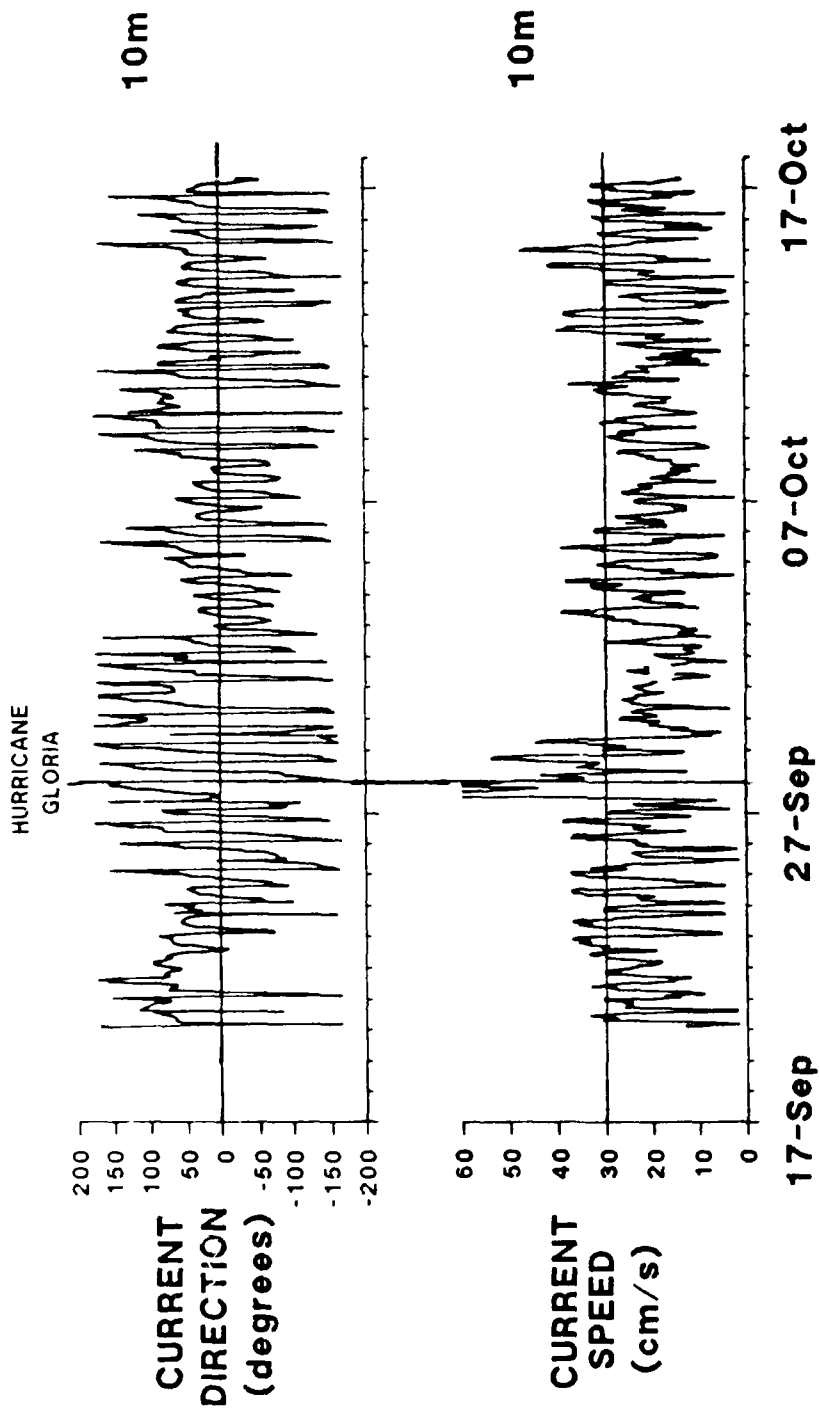


Figure 3.A.2-16. Three-hour low pass (3-HLP) time series of near-surface (10 m) current speed (cm/sec) and direction (°M) at MBDS (20 Sept.-18 Oct., 1985)

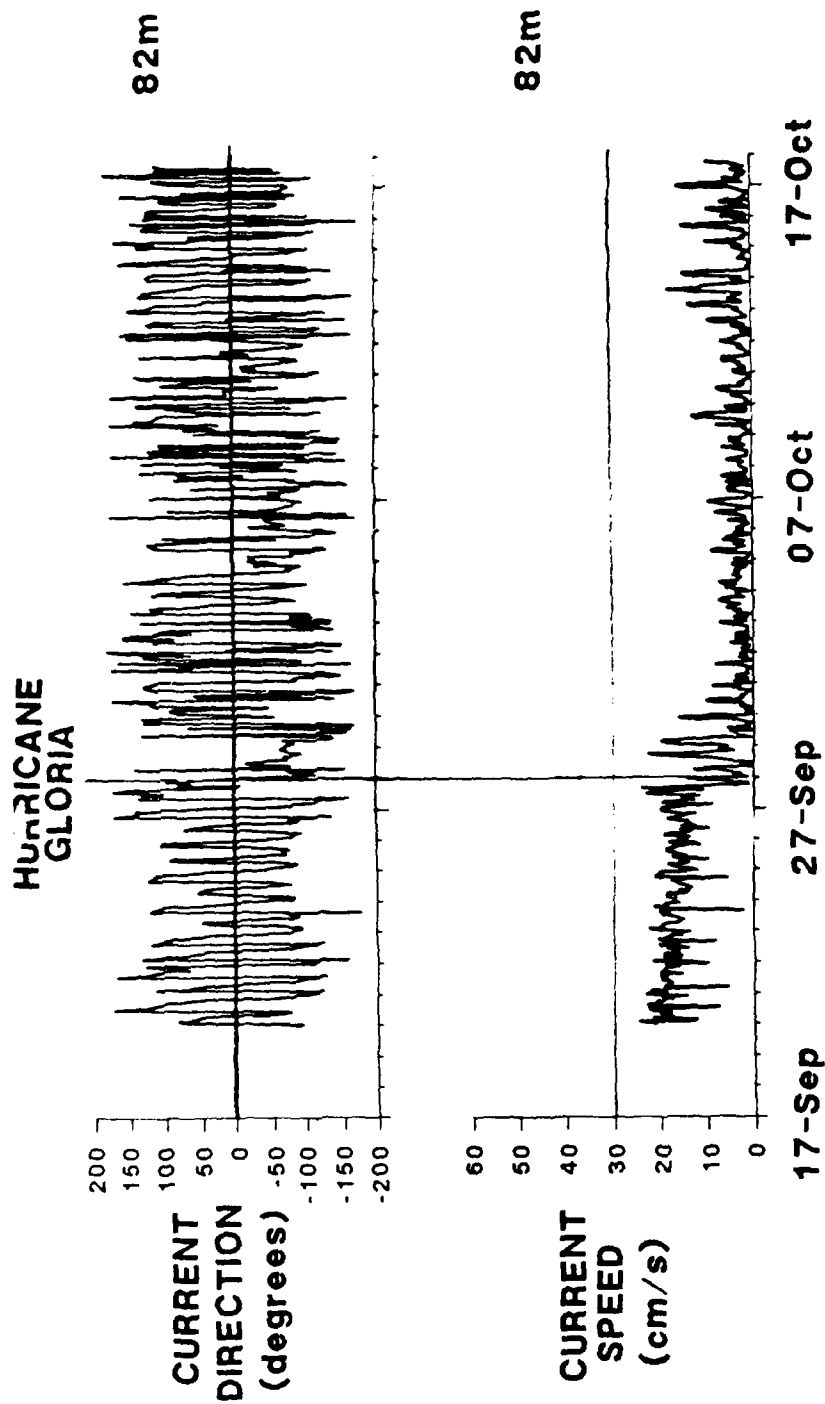


Figure 3.A.2-17 Three-hour low pass (3-HLP) time series of near-bottom (82 m) current speed (cm/sec) and direction ( $^{\circ}$ M) at MBDS (20 Sept.-18 Oct., 1985)



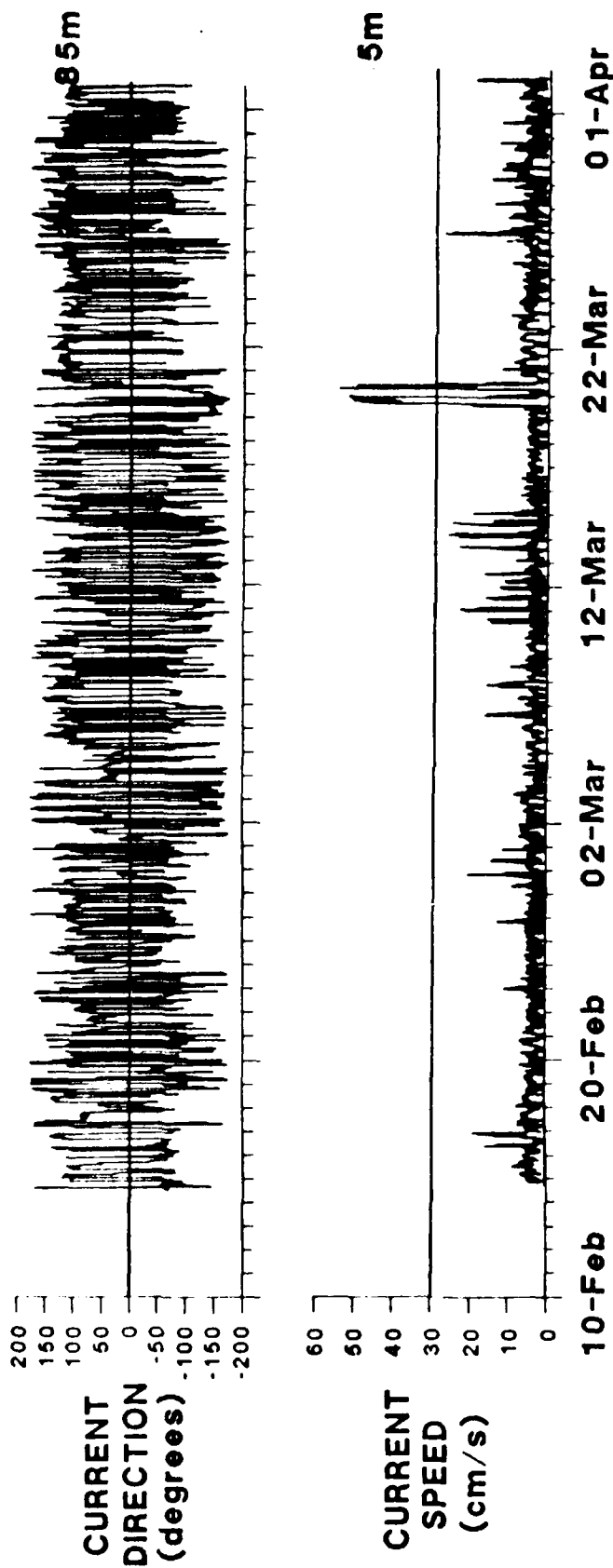


Figure 3.A.2-18 Three-hour low pass (3-HLP) time series of near-bottom (85 m) current speed (cm/sec) and direction ( $^{\circ}$ M) at NBDS (15 Feb. - 2 April, 1985)

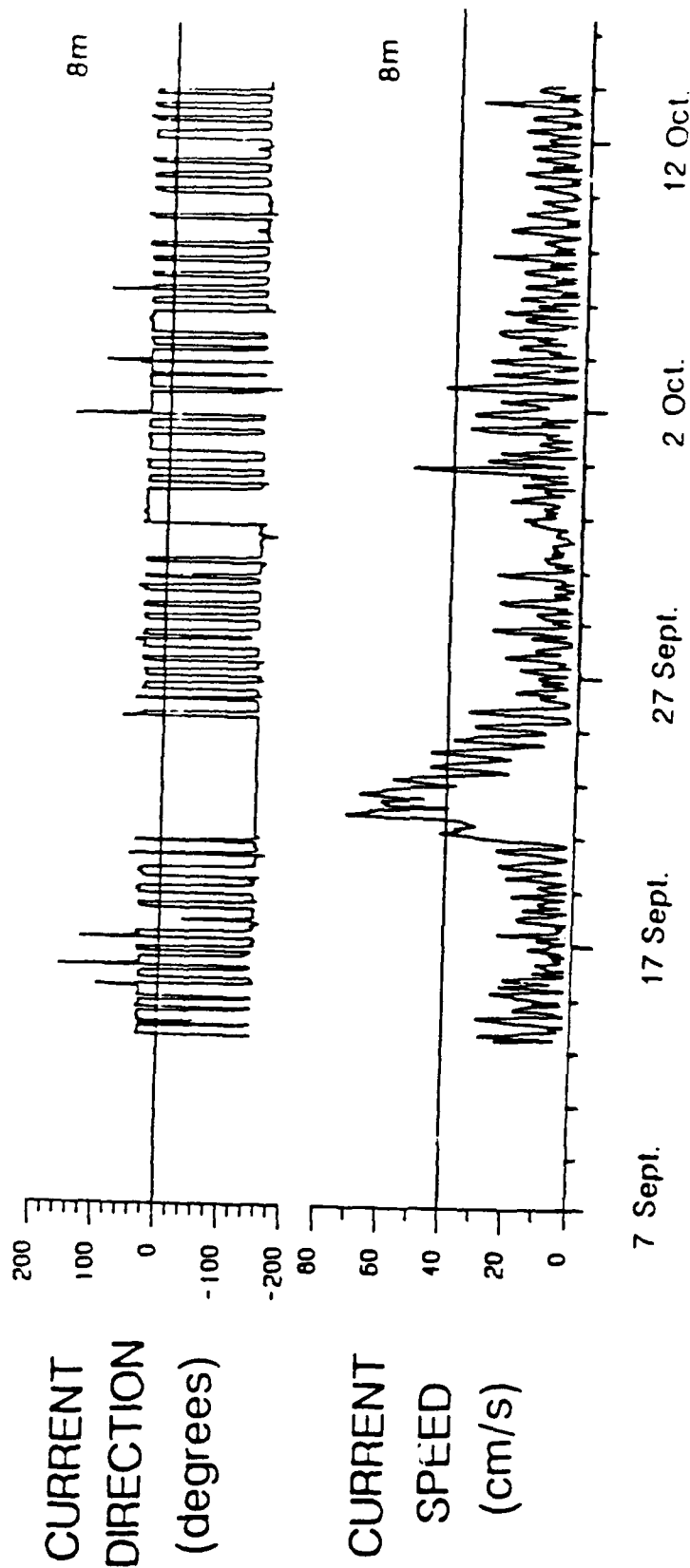


Figure 3.A.2 Three-hour low pass (3-HLP) time series of near-surface (8 m) current speed (cm/sec) and direction ( $^{\circ}$ M) at MBDS (12 Sept.-19 Oct., 1987)

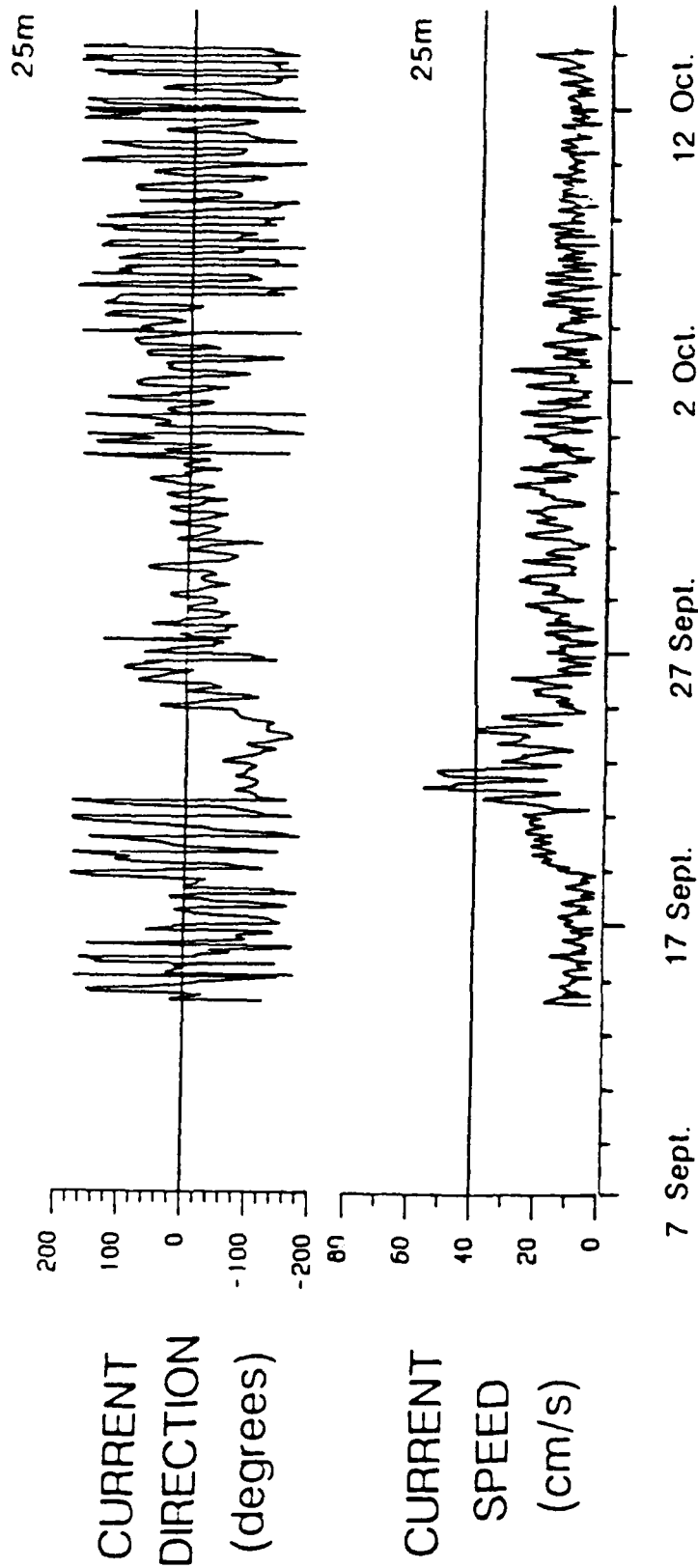


Figure 3.A.2-2C Three-hour low pass (3-HLP) time series of mid-depth (25 m) current speed (cm/sec) and direction ( $^{\circ}$ M) at MBDS (12 Sept.-19 Oct., 1987)

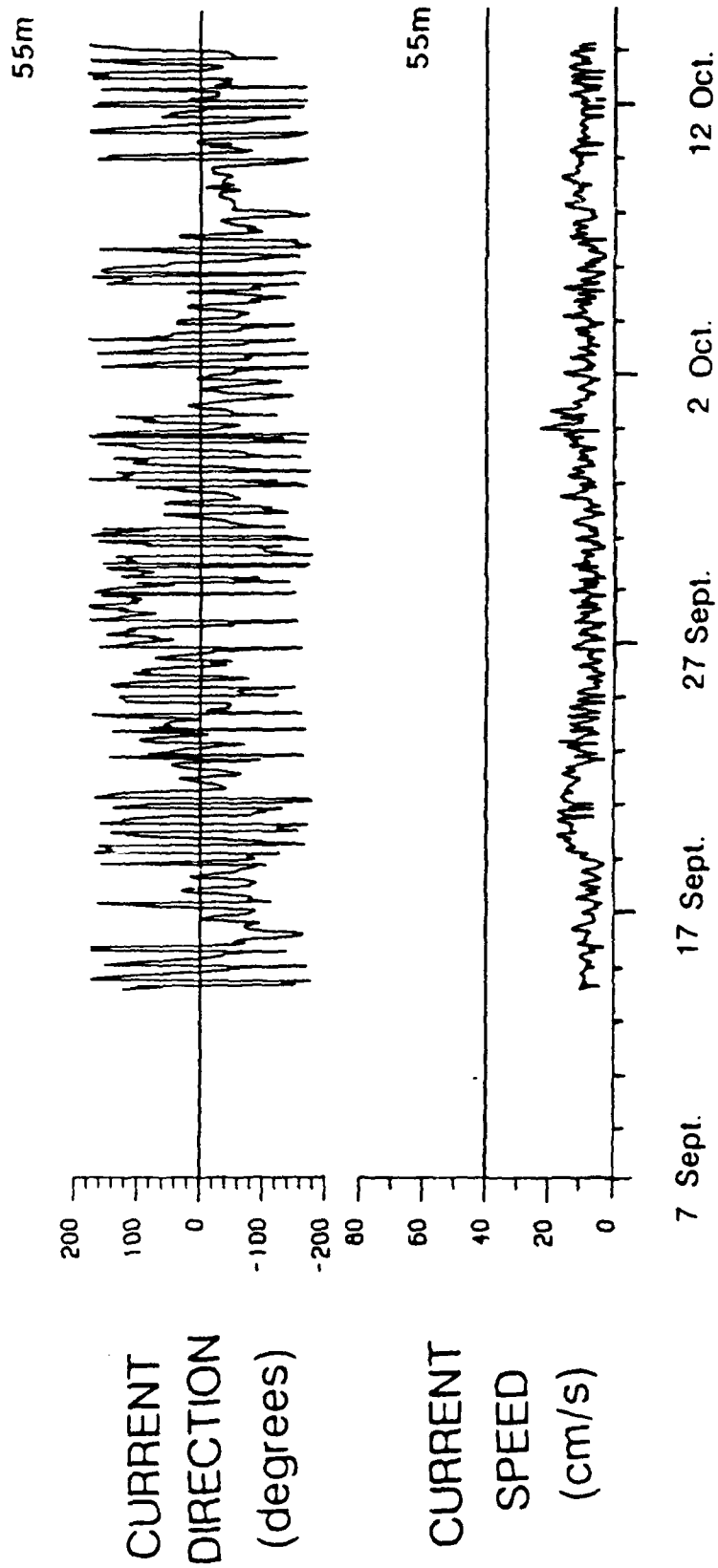


Figure 3.A.2-21 Three-hour low pass (3-HLP) time series of mid-depth (55 m) current speed (cm/sec) and direction (°M) at MBDS (12 Sept.-19 Oct., 1987)

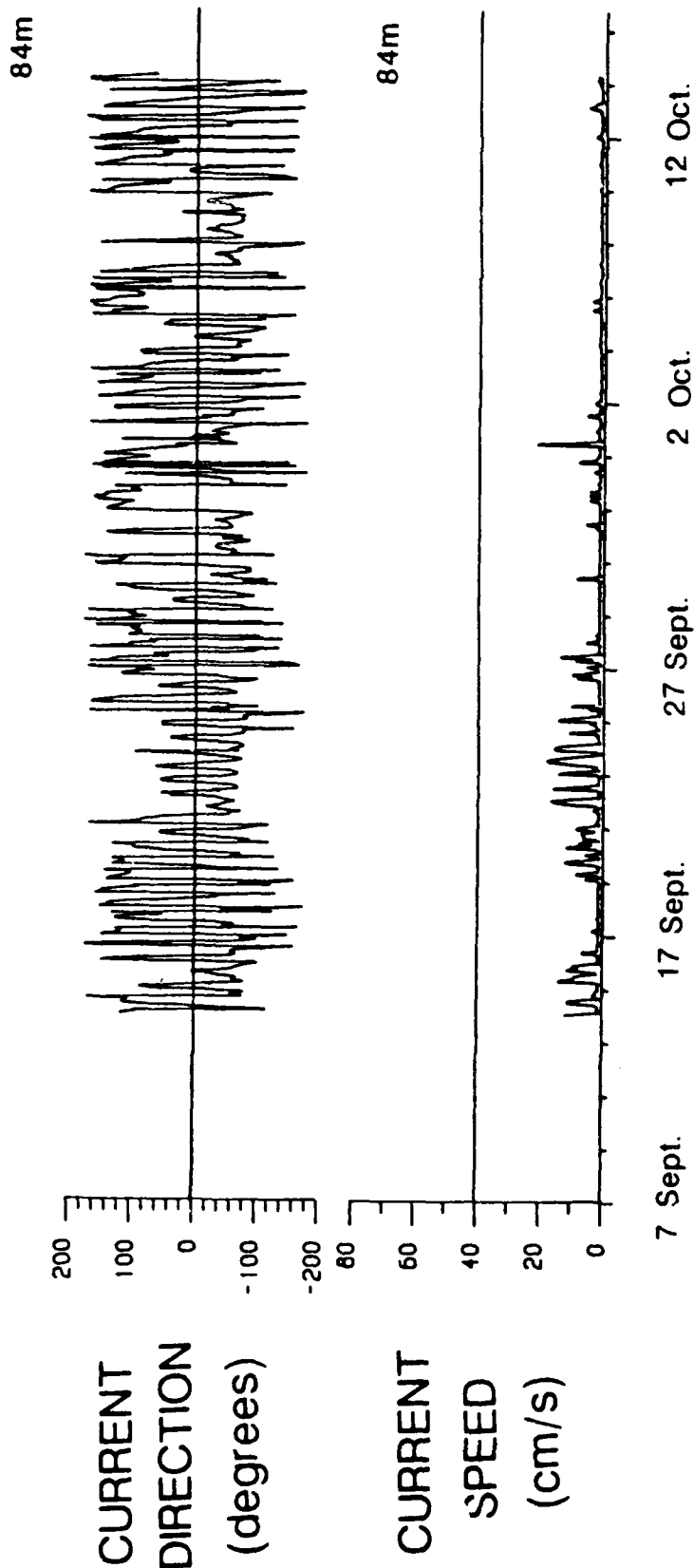
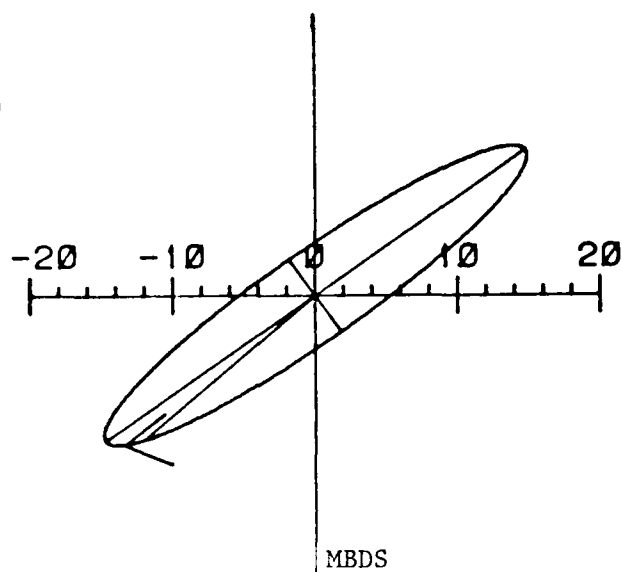
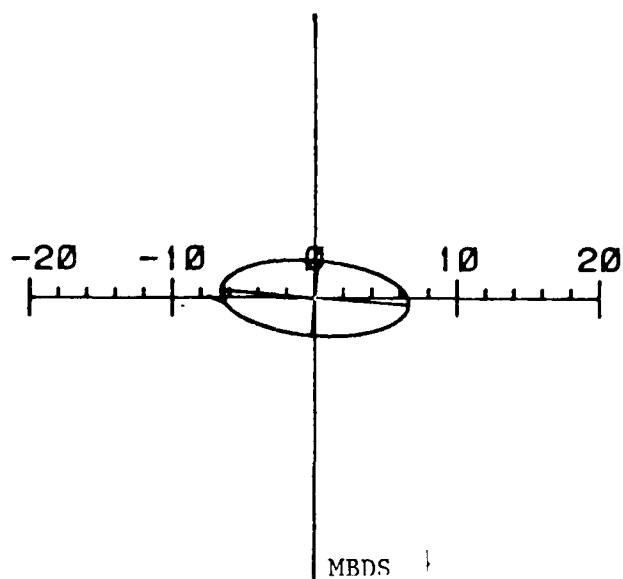


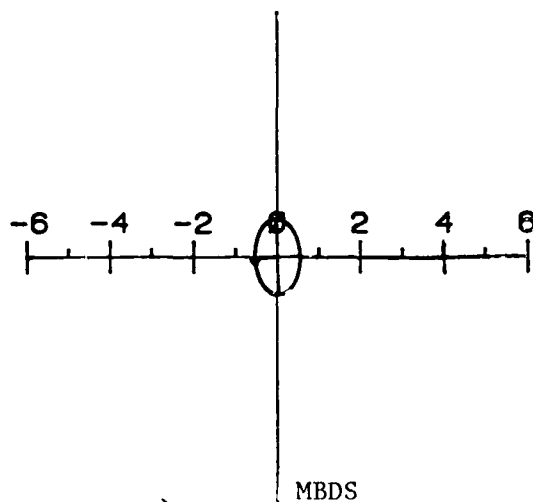
Figure 3.A.2-22 Three-hour low pass (3-HLP) time series of near-bottom (84 m) current speed (cm/sec) and direction ( $0^\circ$ ) at MBDS (12 Sept.-19 Oct., 1987)



Near-Surface (10 m)  
September - October 1985



Near-Bottom (82 m)  
September - October 1985



Near-Bottom (85 m)  
February - April 1986

**Figure 3.A.2-23a** Comparison of tidal ellipses calculated from near-surface (10 m) and near-bottom (82 and 85 m) current meter data at MBDS (20 Sept. - 18 Oct., 1985 and 15 Feb. - 2 April, 1986)

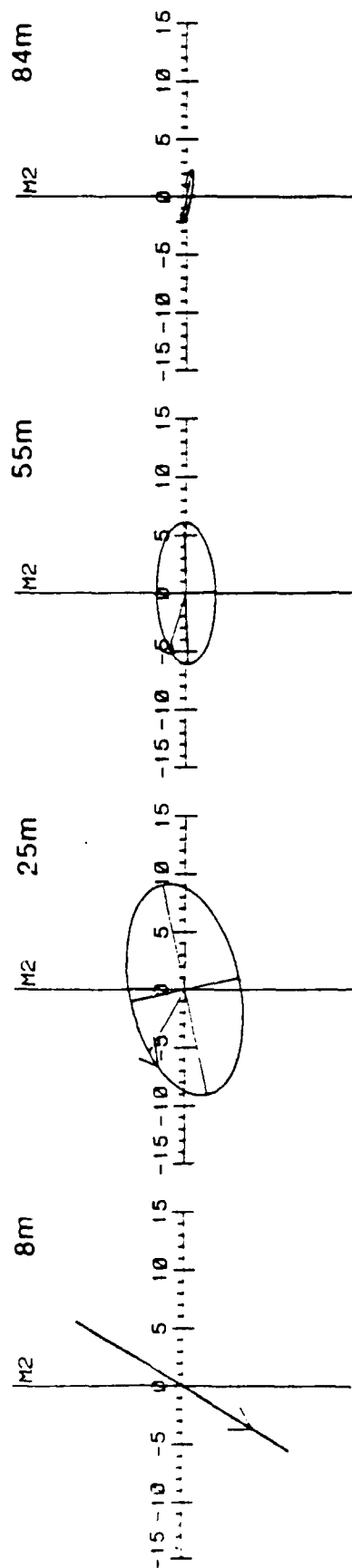


Figure 3.A.2-23b Comparison of tidal ellipses calculated from data at the four current meter depths at MBDS (12 Sept. - 19 Oct., 1987)

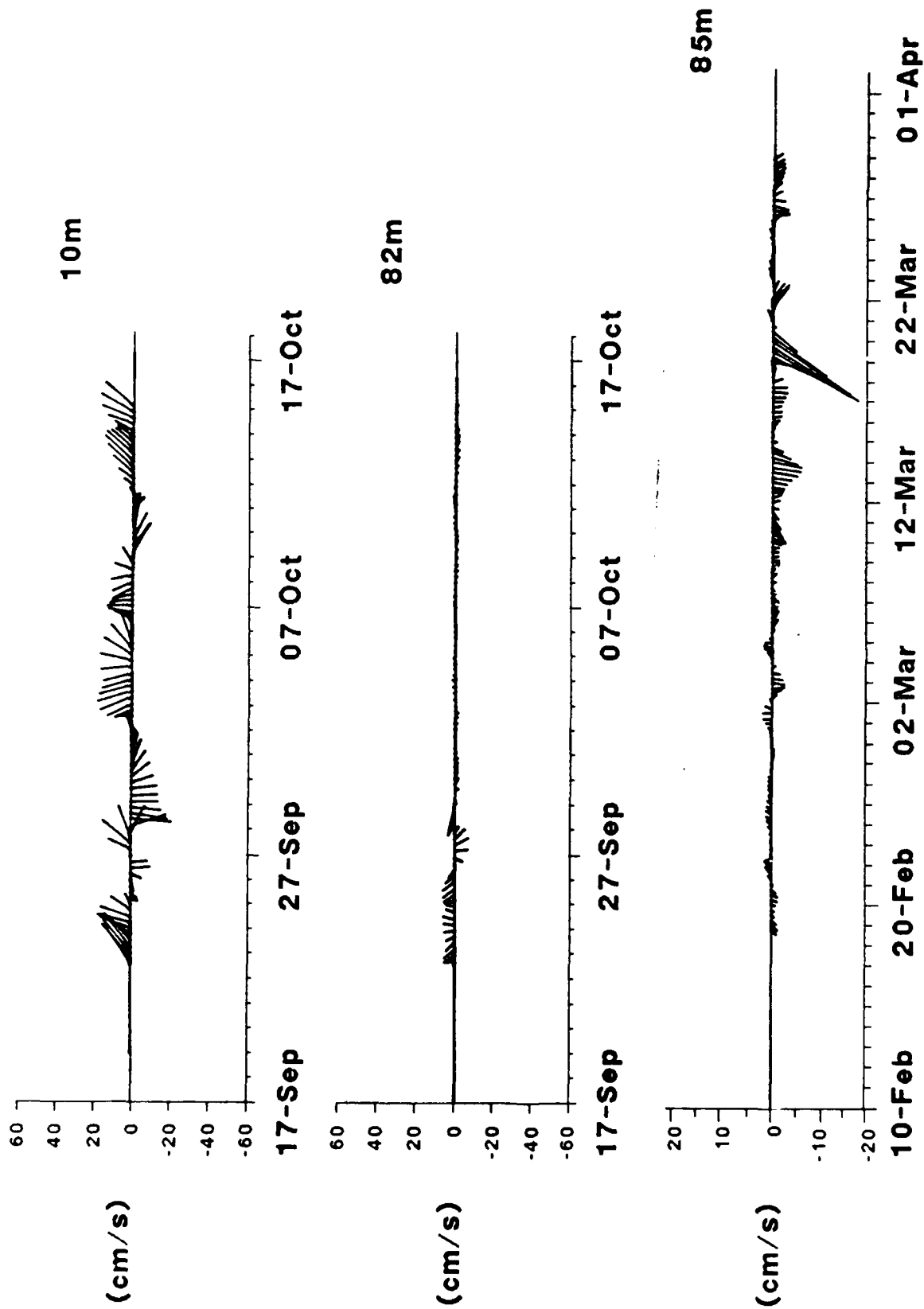
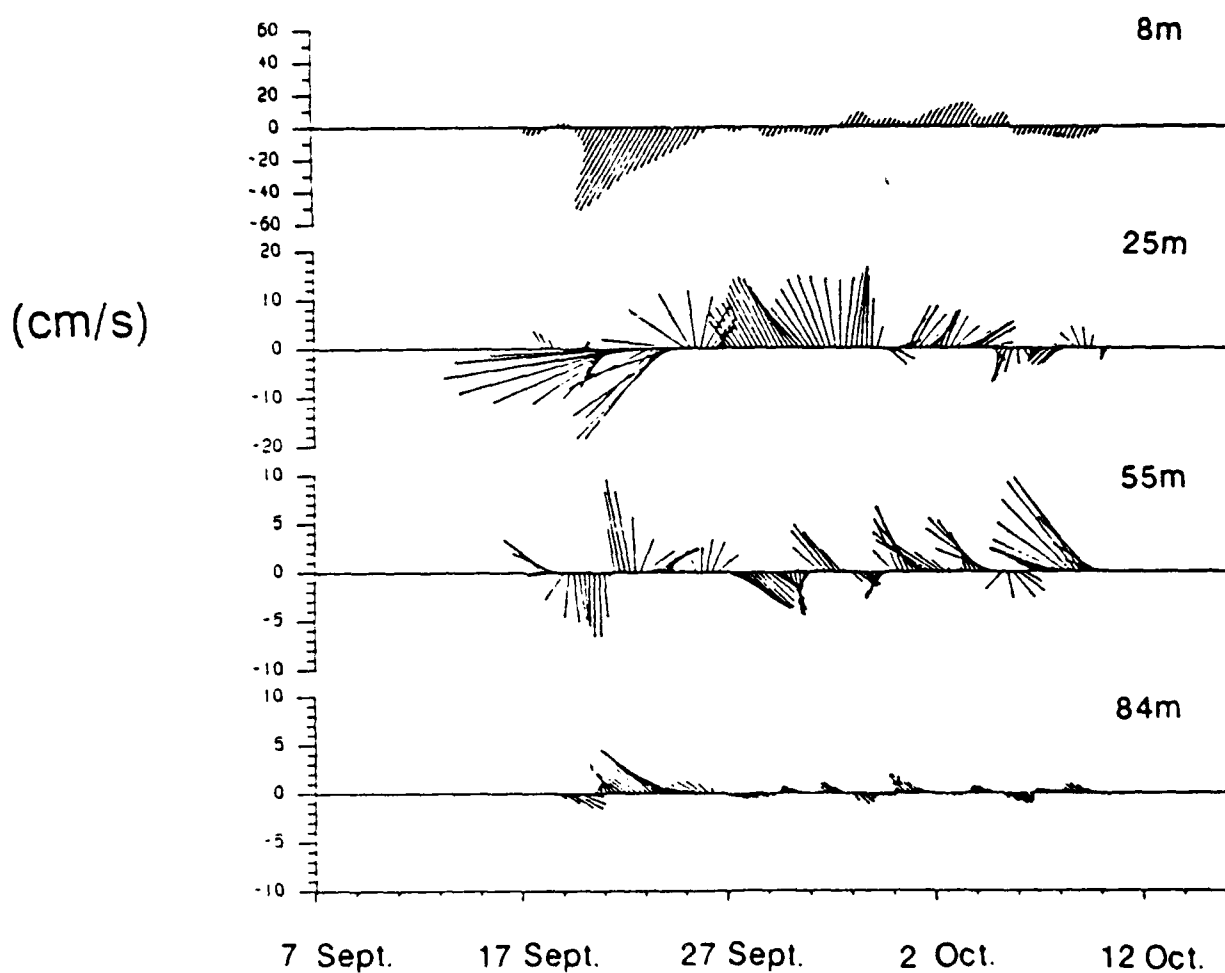
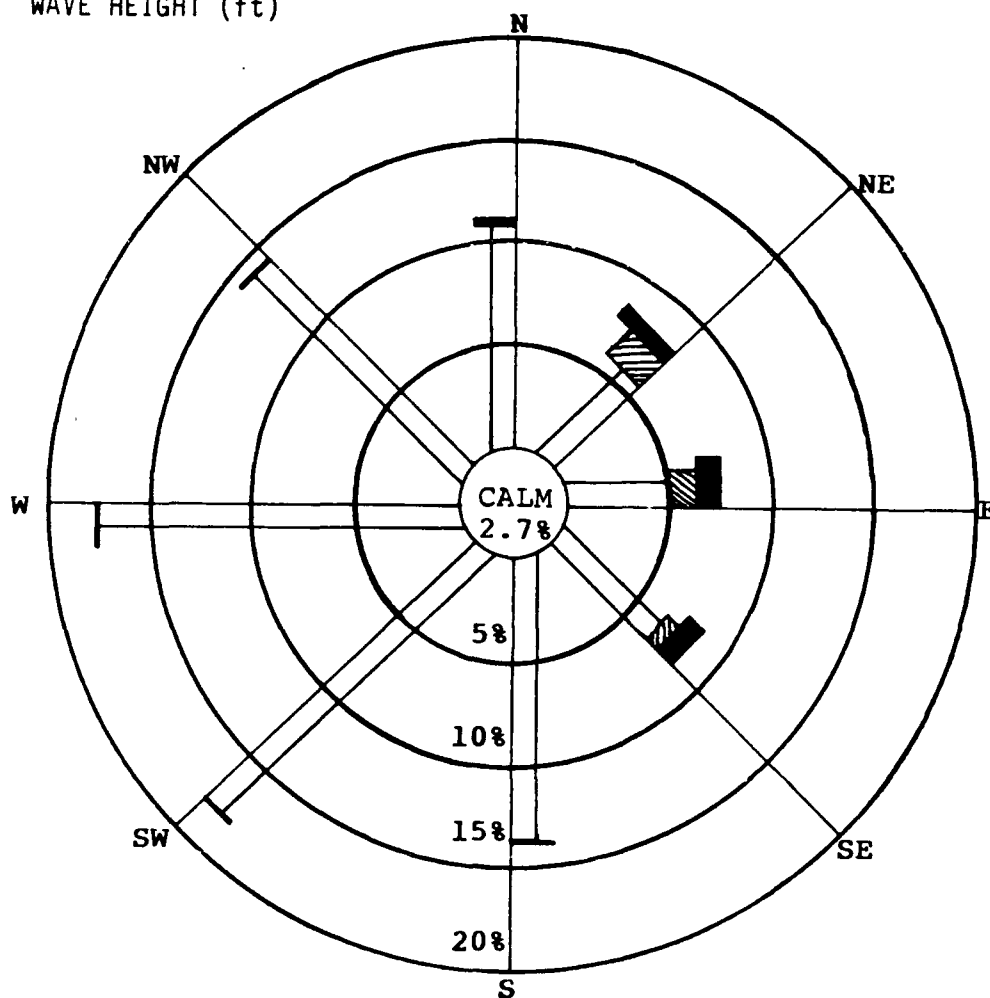
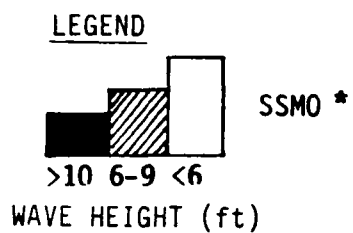


Figure 3.A.2-24a Forty-hour low pass (40-HLP) time series of near-surface (10 m) and near-bottom (82 and 85 m) current meter data collected at MBDS (20 Sept. - 18 Oct., 1985 and 15 Feb. - 2 April, 1986). (Note change in Y-axis scale).





**Figure 3.A.2-24b** Forty-hour low pass (40-HLP) time series of current meter data collected at four depths at MBDS (12 Sept. - 19 Oct., 1987). (Note change in Y-axis scale.)



\* Summary of Synoptic Meteorological Observations (U.S. Naval Weather Service Command).

**Figure 3.A.2-25** Surface wave rose representative of Massachusetts Bay (from Raytheon, 1974).

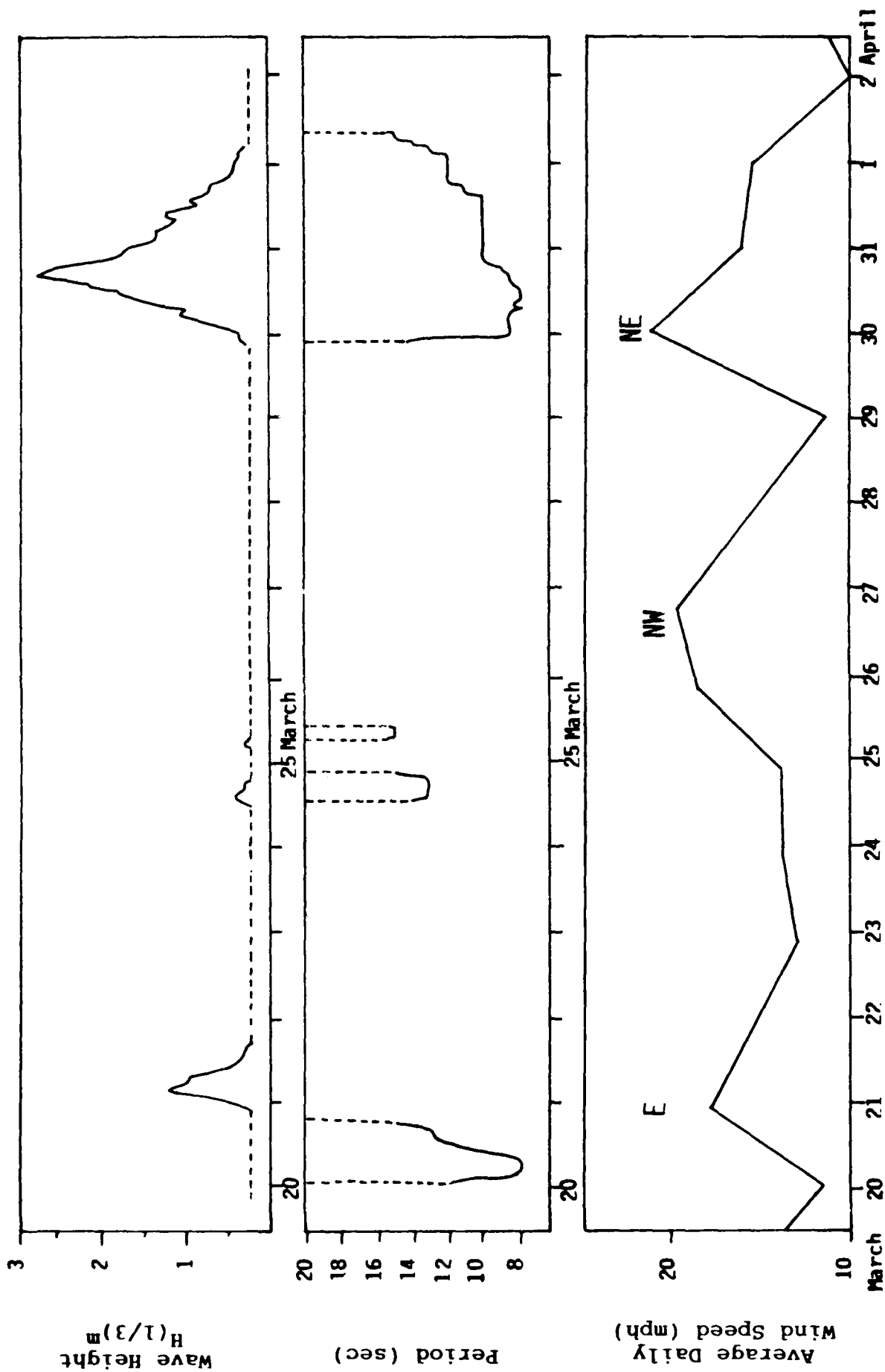


Figure 3.A.2-26 In-situ wave height ( $H(1/3)$ ) and period (sec) measured in Massachusetts Bay ( $42^{\circ}26'N$ ,  $70^{\circ}43'W$ ) compared with average daily wind speeds (mph) measured at Boston (20 March - 3 April, 1974) (from Raytheon, 1974)

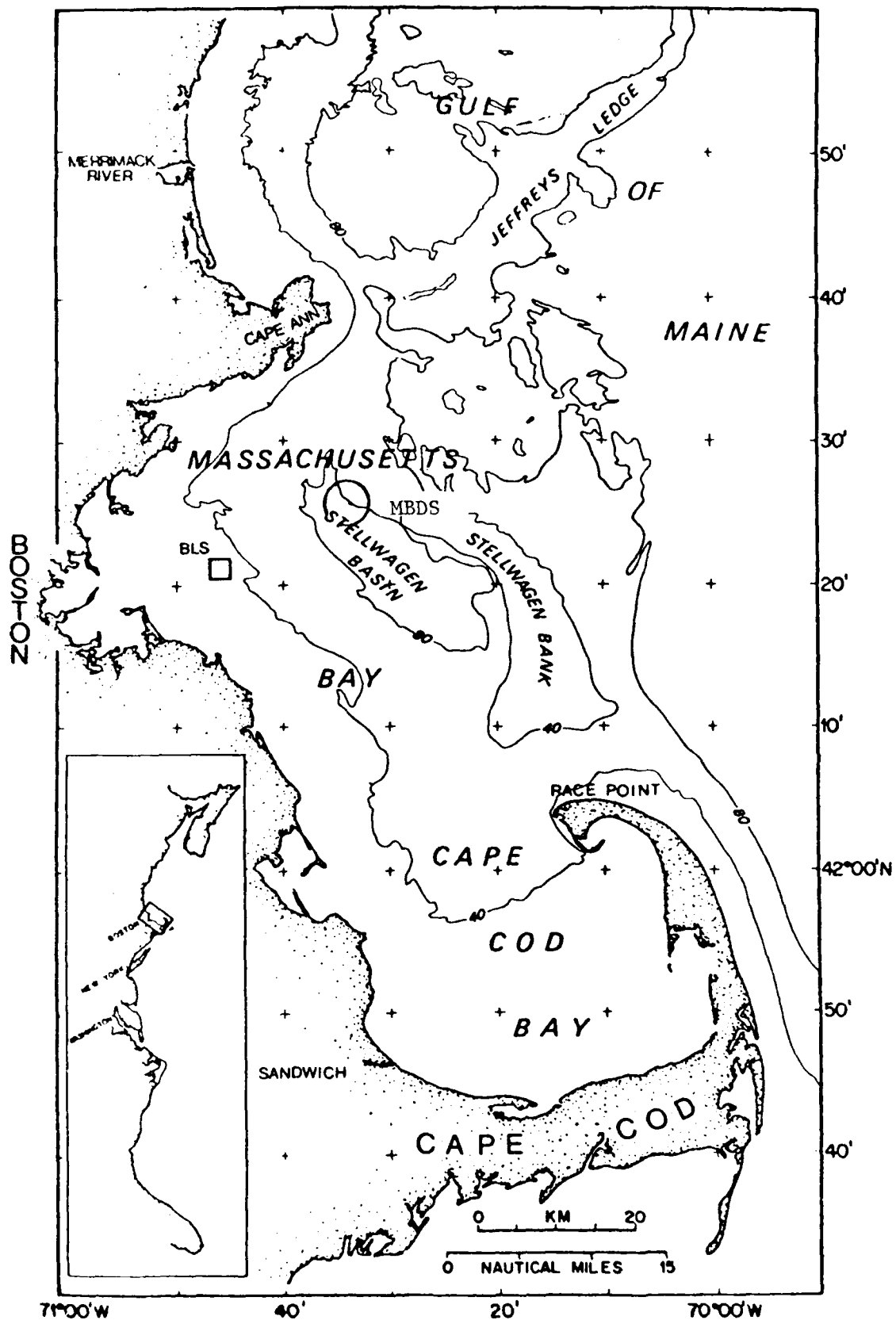


Figure 3.A.2-27 Major bathymetric features of Massachusetts Bay  
(from Butman, 1977)

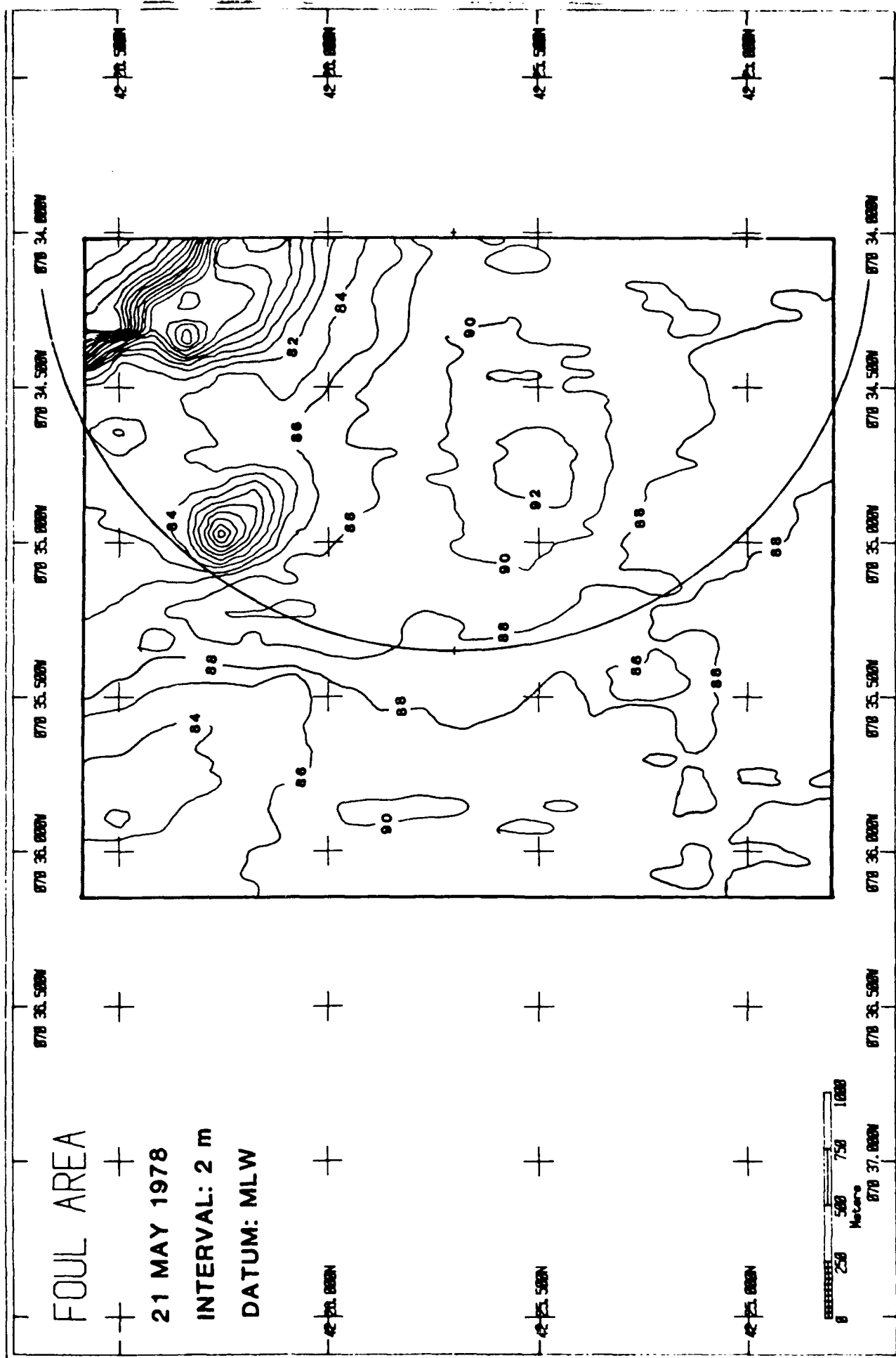
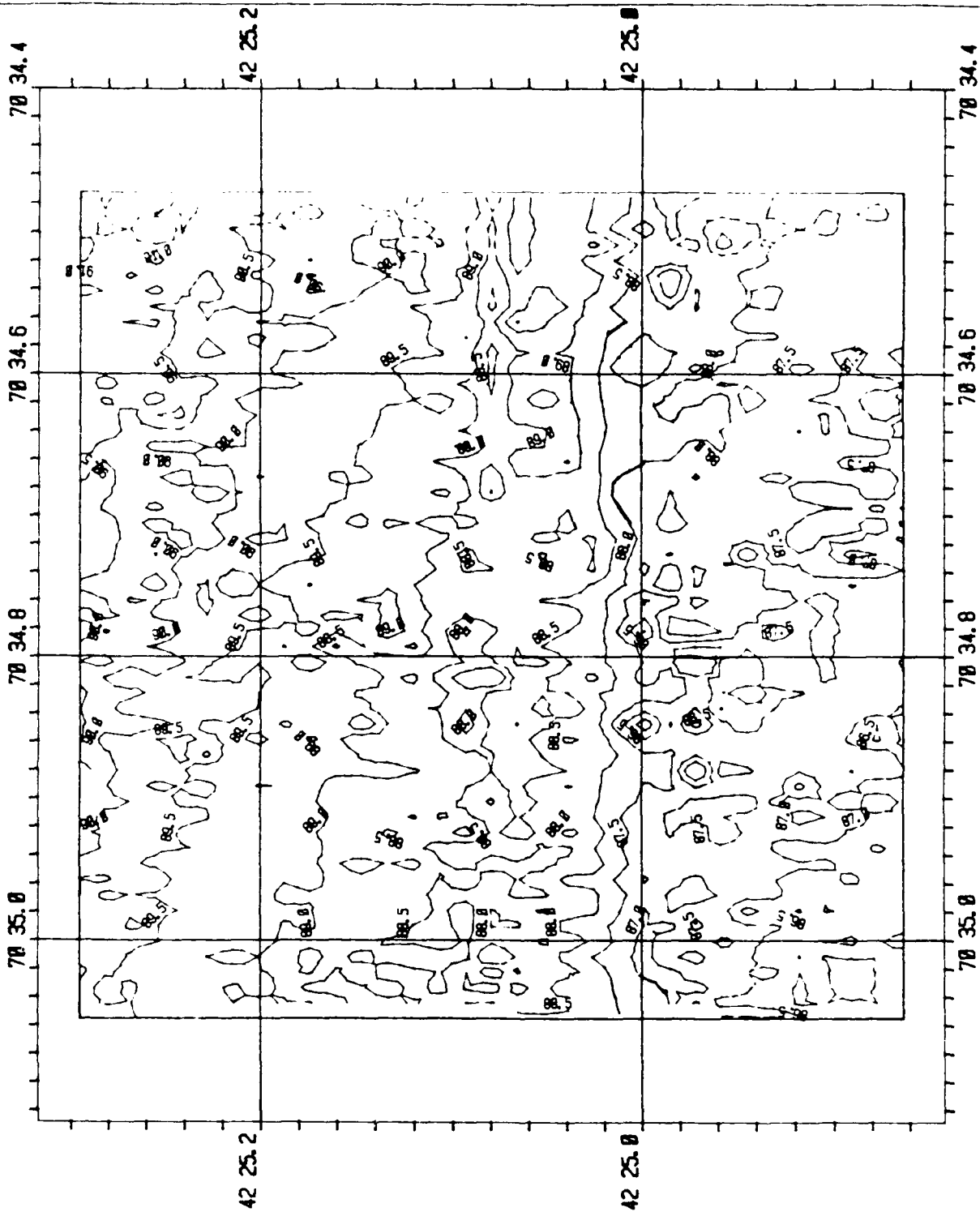
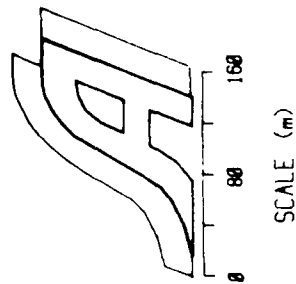


Figure 3.A.2-28 Contour chart of bathymetric data collected at MBDS (21 May, 1978) (NUSC, 1979)

# **BOSTON FOUL GROUND SOUTH**

**JANUARY 1983  
SCALE: 1/4000  
INTERVAL: .5**



**Figure 3.A.2-29** Contour chart of bathymetric data collected at  
Mass. Bay - South Site (January, 1983) (SAIC,  
1985)



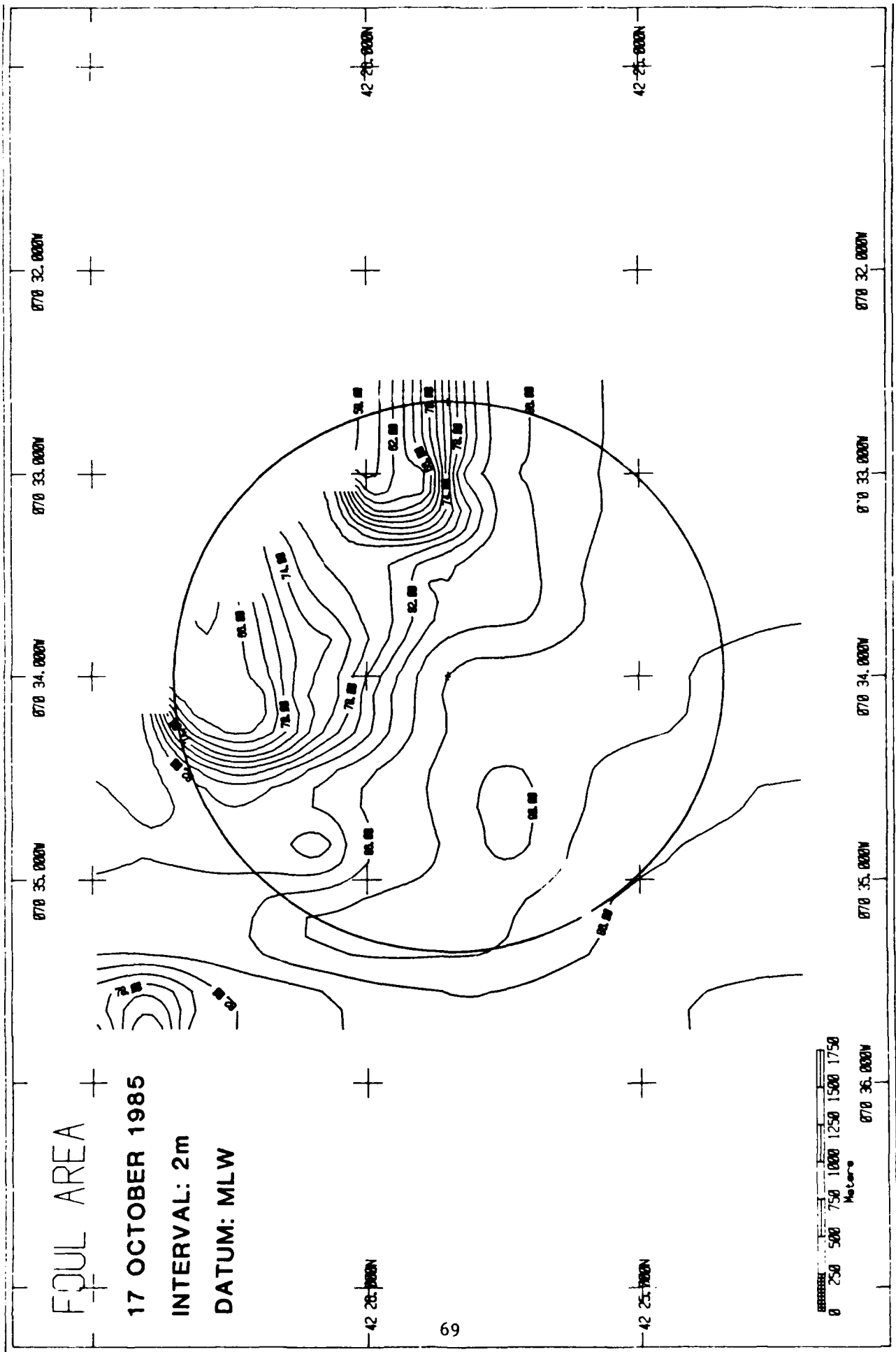


Figure 3.A.2-31 Contour chart of bathymetric data collected at  
MRDS (October, 1985)



# FOUL AREA DISPOSAL SITE

17 OCTOBER 1985

VERTICAL EXAGGERATION: 40X

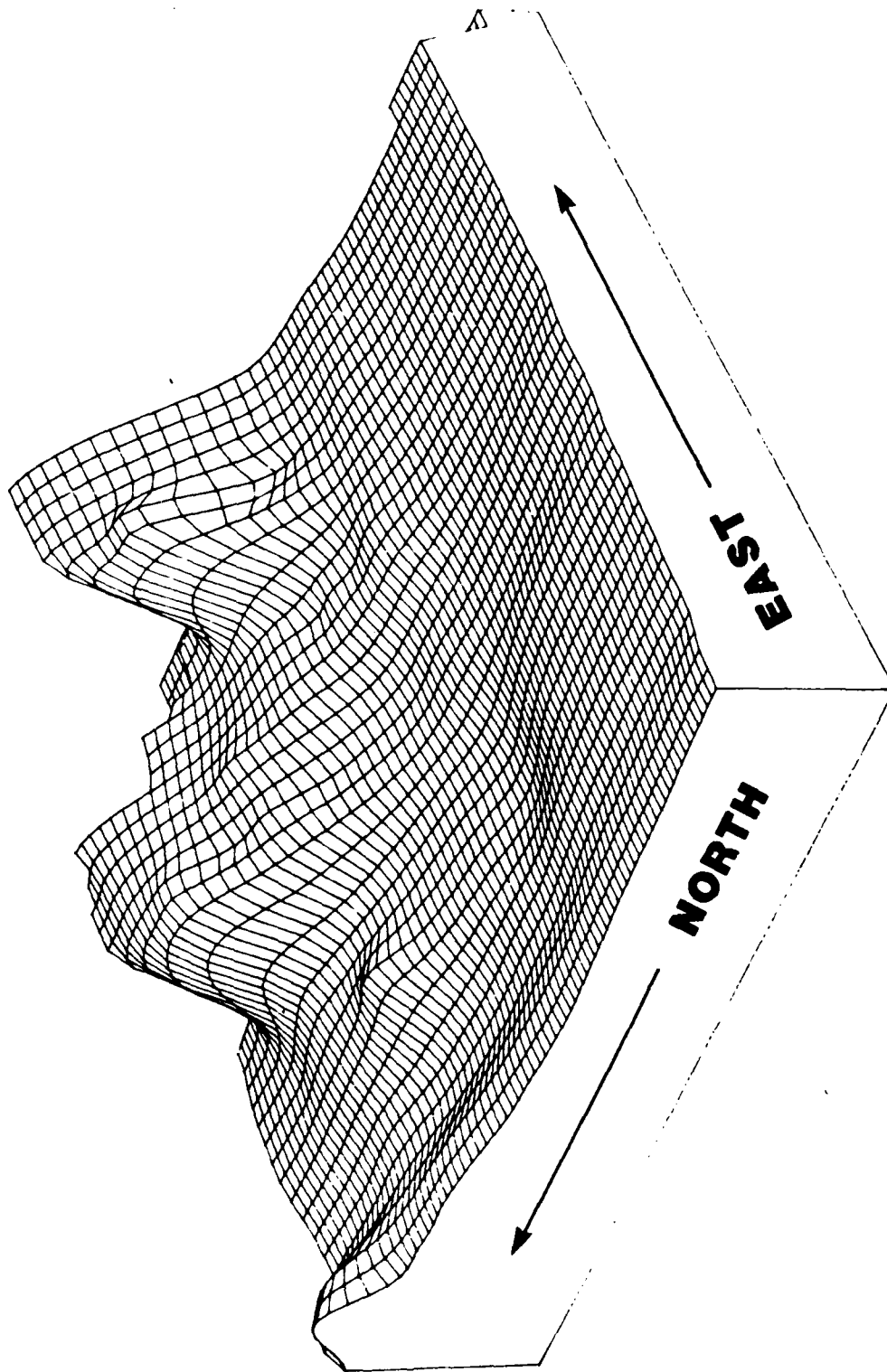


Figure 3.A.2-32 Three dimensional representation of bathymetric data collected at MBDS (October, 1985)

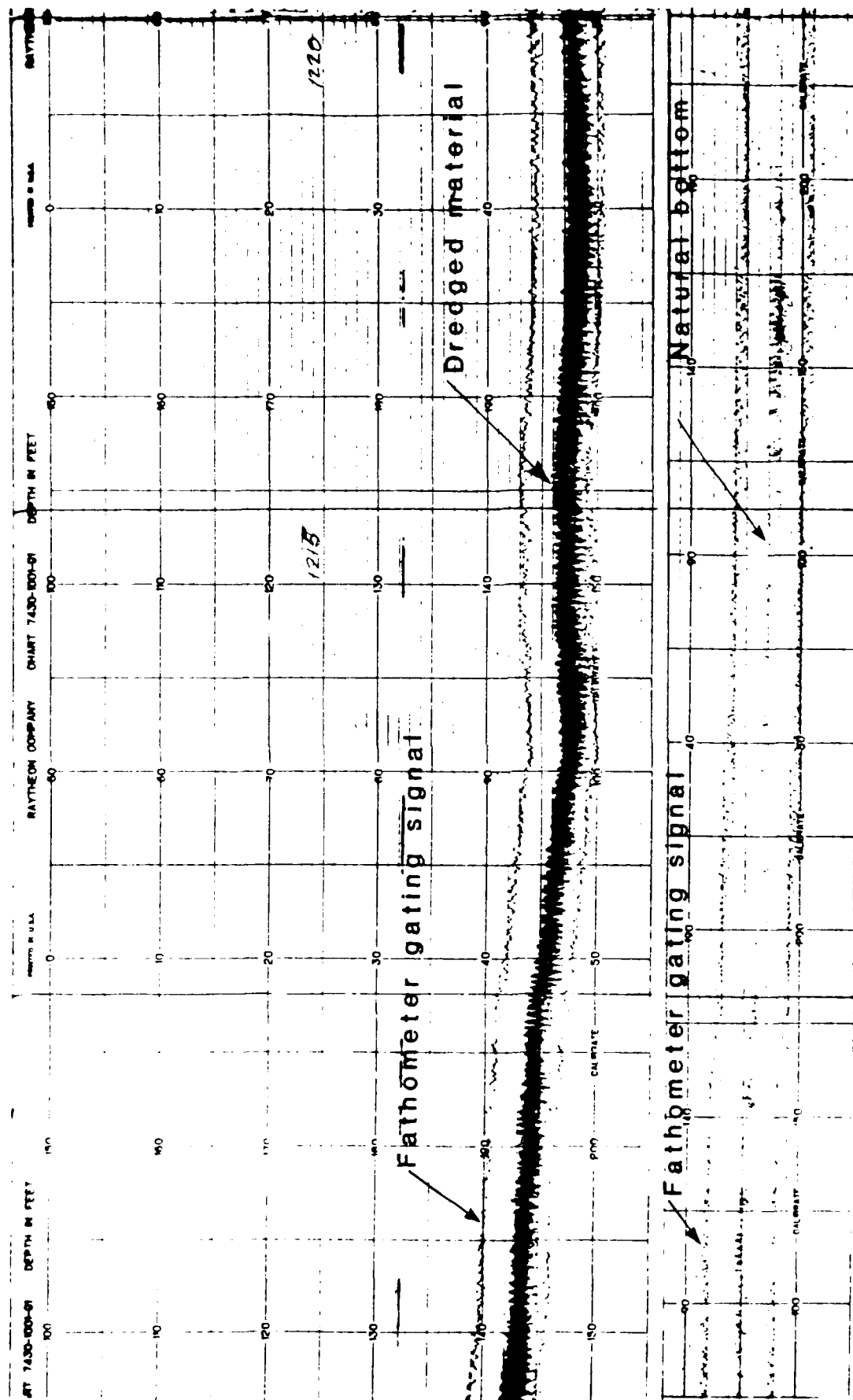


Figure 3.A.2-33 Comparison of fathometer records recorded over dredged material and natural bottom at MRDS (October, 1985)

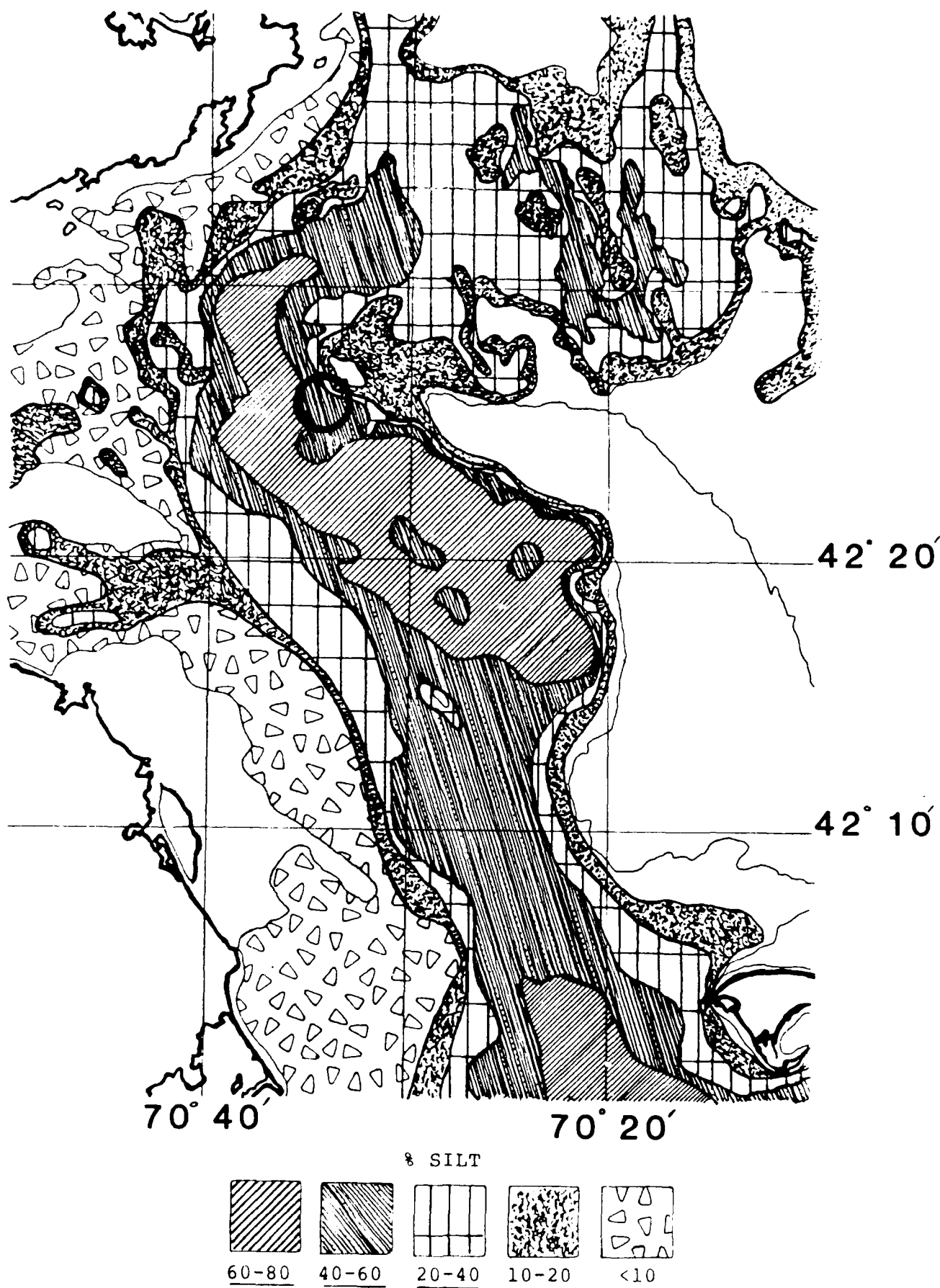


Figure 3.A.2-34 Distribution of the percentage of silt sized particles in sediments deposited in Massachusetts Bay (from Schlee et al., 1973)

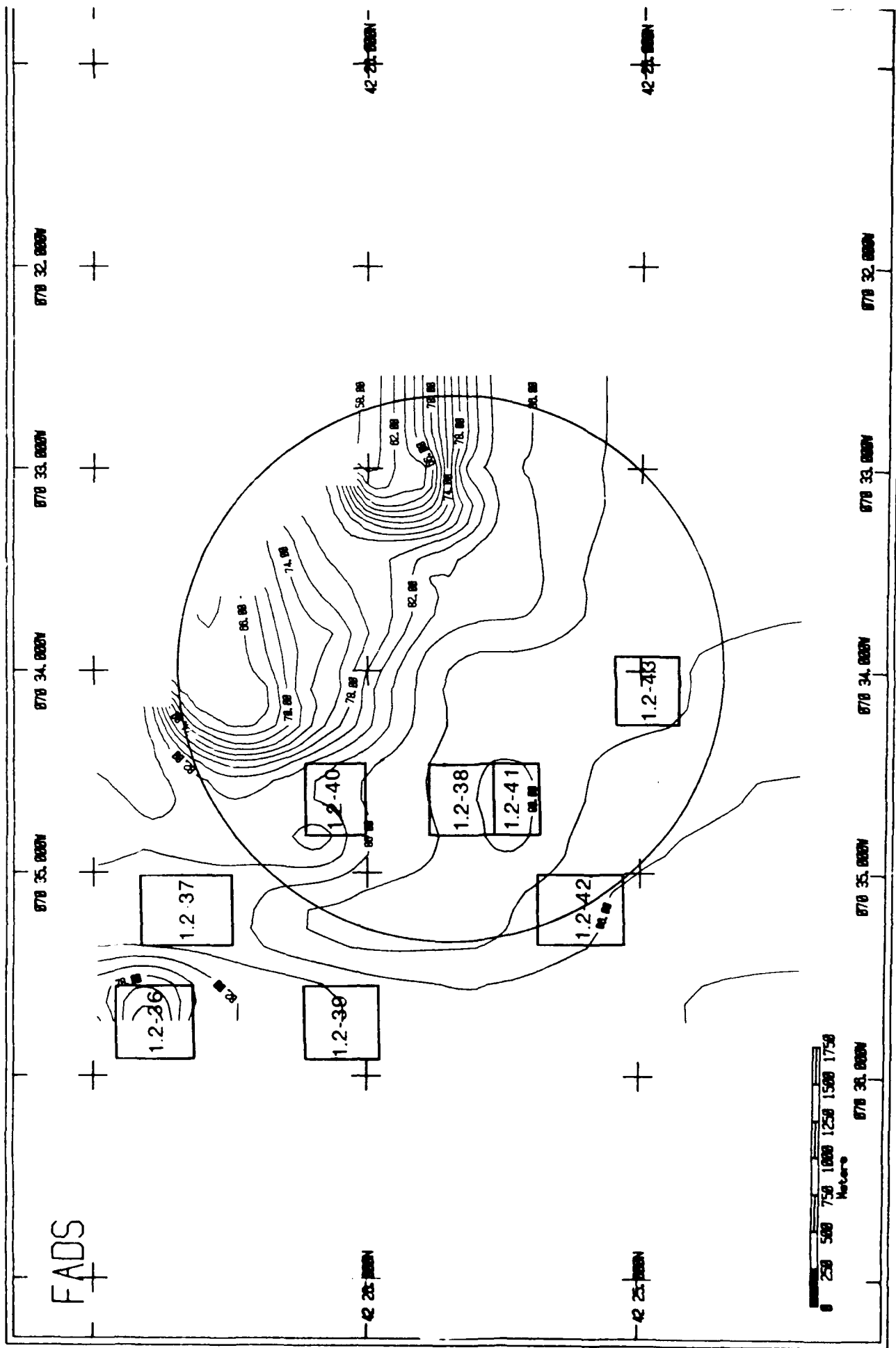


Figure 3.A.2-35 Location of side scan sonar records used to characterize the sediment facies within the MBDS region (October, 1985)

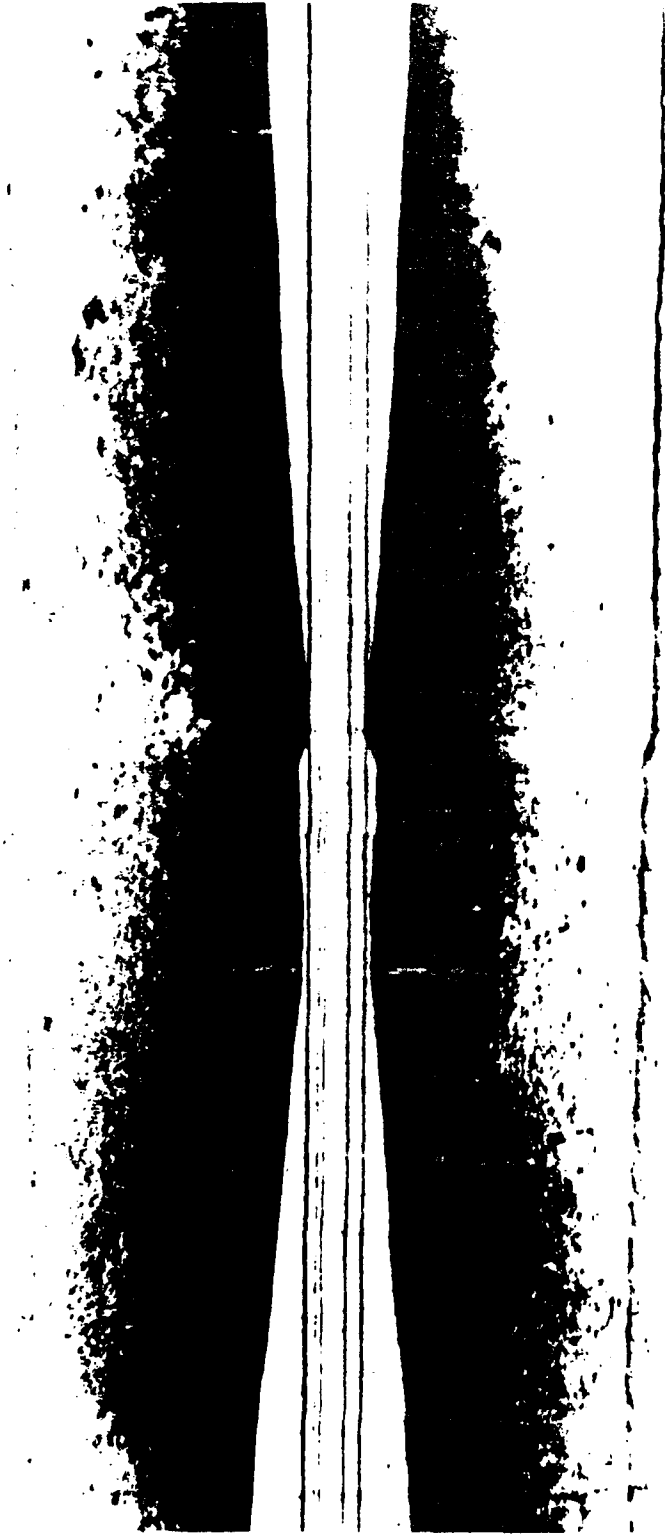


Figure 3.A.2-36 Type "1" side scan sonar record in general area of MBDS (October, 1985)  
Hard bottom with sand, gravel and exposed rock associated with shoaling in  
the northeast quadrant of the site.



Figure 3.A.2-37 Type "2" side scan sonar record in general area of MBDS (October, 1985)  
Soft, natural silt bottom with distinctive acoustic targets, probably caused  
by chemical or low-level radioactive waste containers (indicated by arrows).

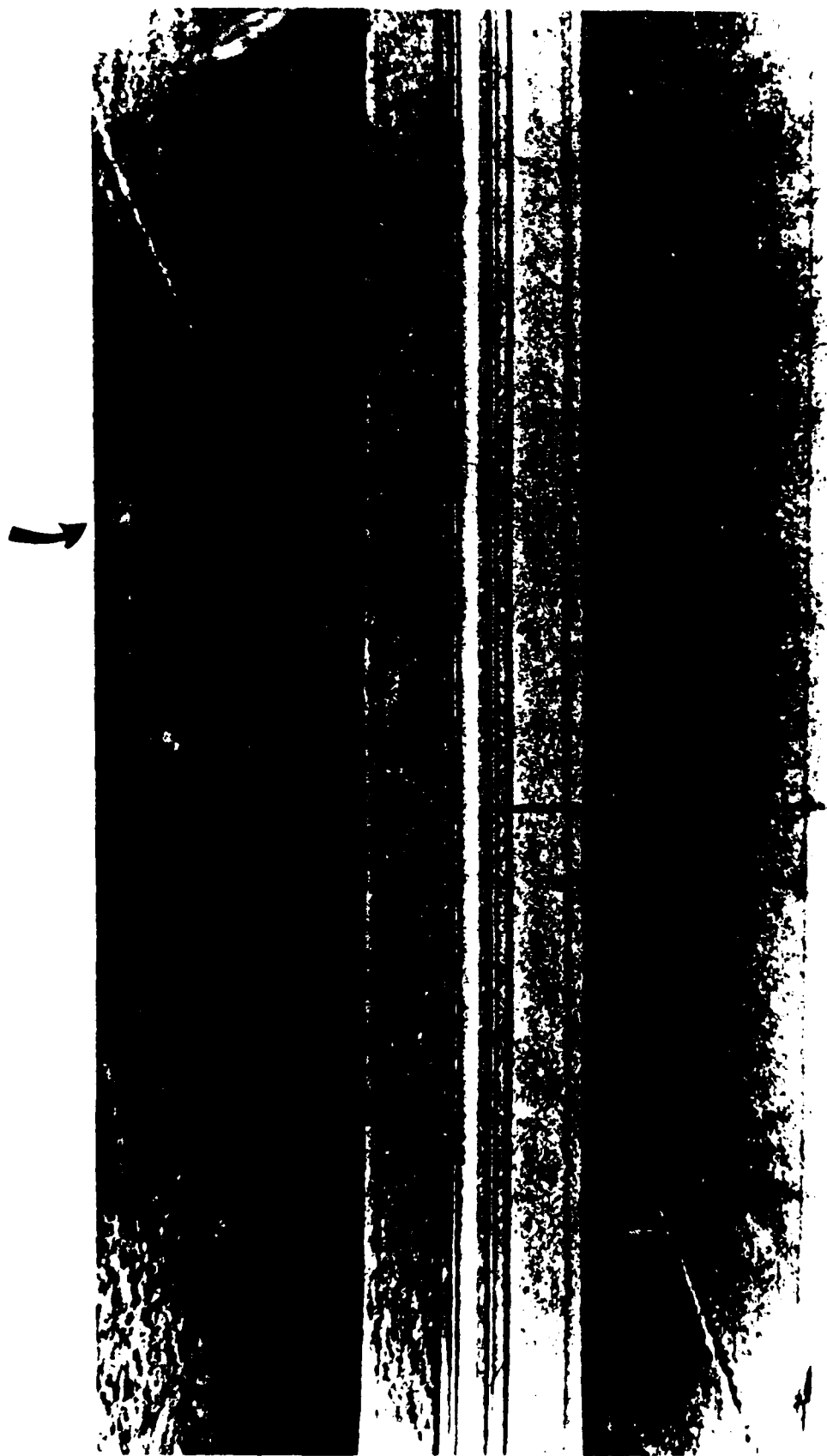


Figure 3.A.2-38 Type "3a" side scan sonar record, MBDS (October, 1985) Coarse dredged material deposit near the disposal buoy with accumulation of large cohesive clay clumps (identified by white shadows as indicated by arrows).

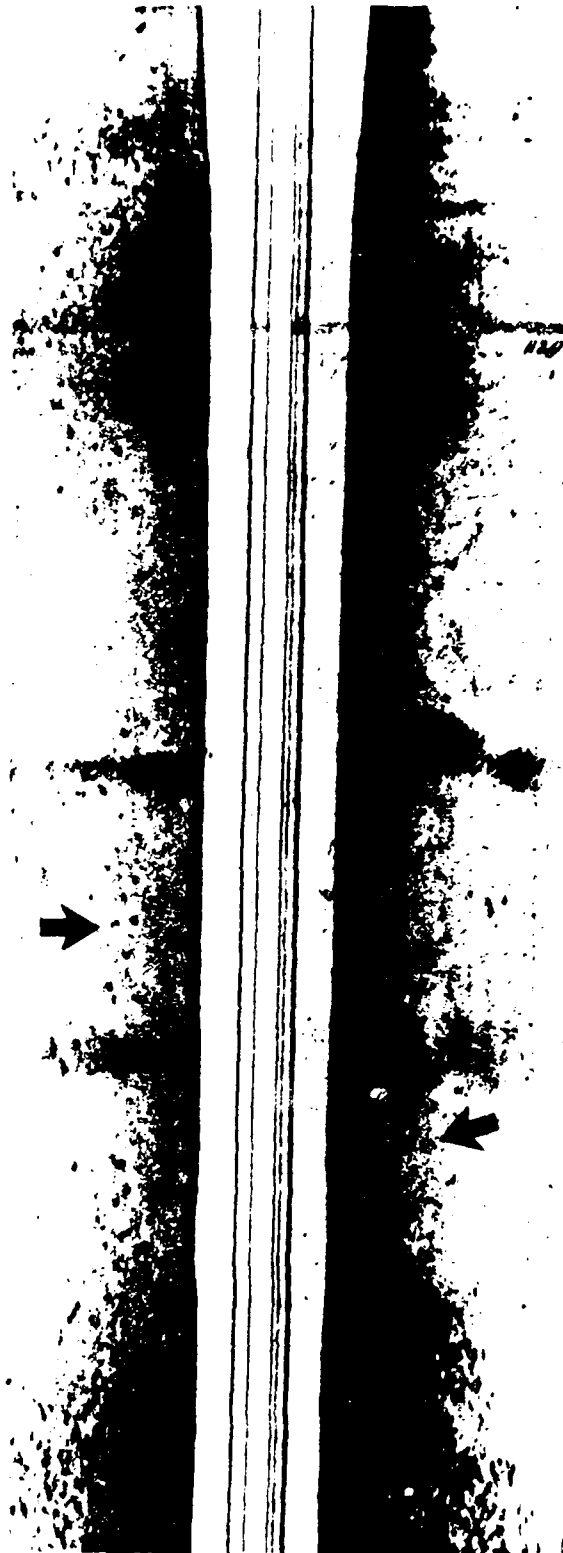


Figure 3.A.2-39 Type "3b" side scan sonar record in general area of MBDS (October, 1985)  
Isolated mounds of coarse dredged material at a significant distance (1500 m) from the disposal buoy. Acoustic targets, probably caused by chemical or low-level radioactive waste containers (indicated by arrows) are present in this area, some of which are most likely covered by dredged material.



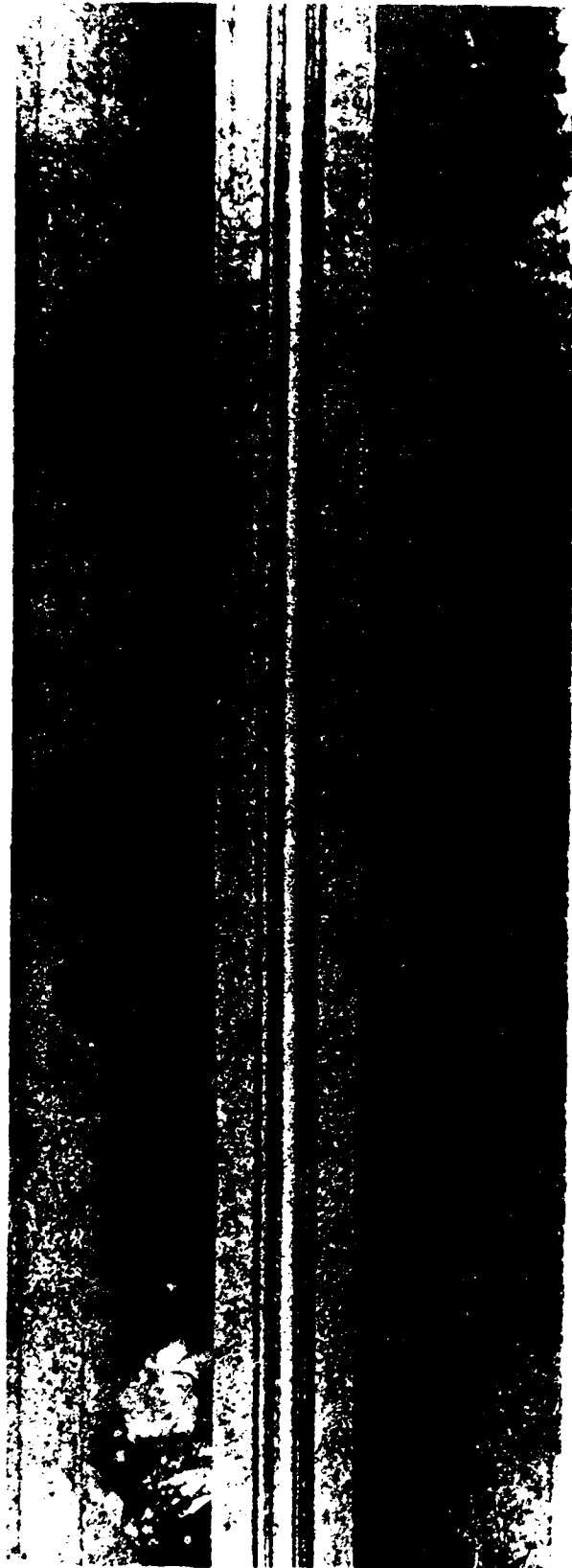


Figure 3.A.2-40 Type "3c" side scan sonar record, MBDS (October, 1985) Circular, high reflectance areas in a linear pattern are indicative of dredged material disposal activity. Acoustic targets, probably caused by chemical or low-level radioactive waste containers (indicated by arrows) are present in this area, some of which are most likely covered by dredged material.

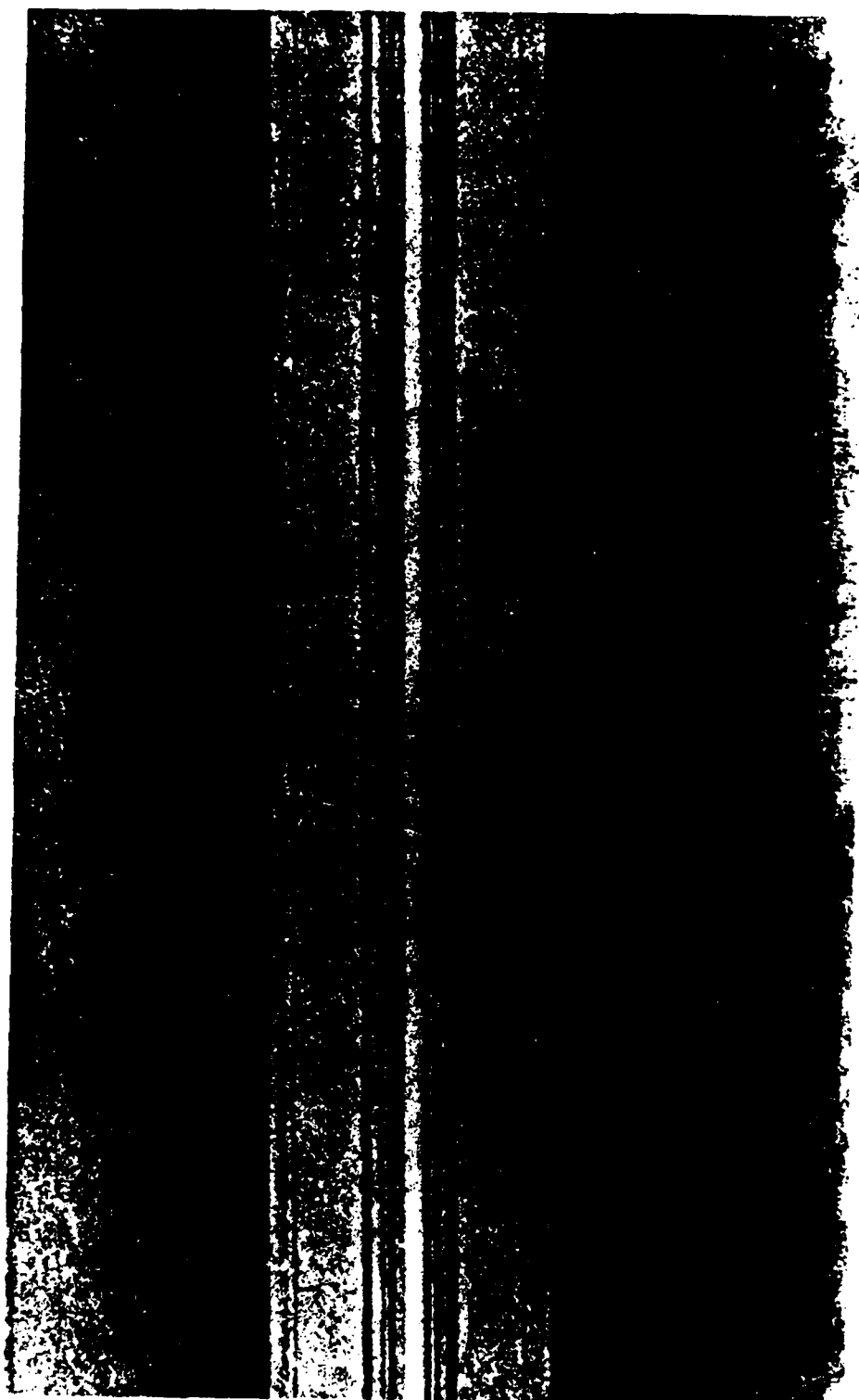


Figure 3.A.2-41 Type "3c" side scan sonar record, MBDS (October, 1985) Circular, high reflectance areas in a linear pattern are indicative of dredged material disposal activity.

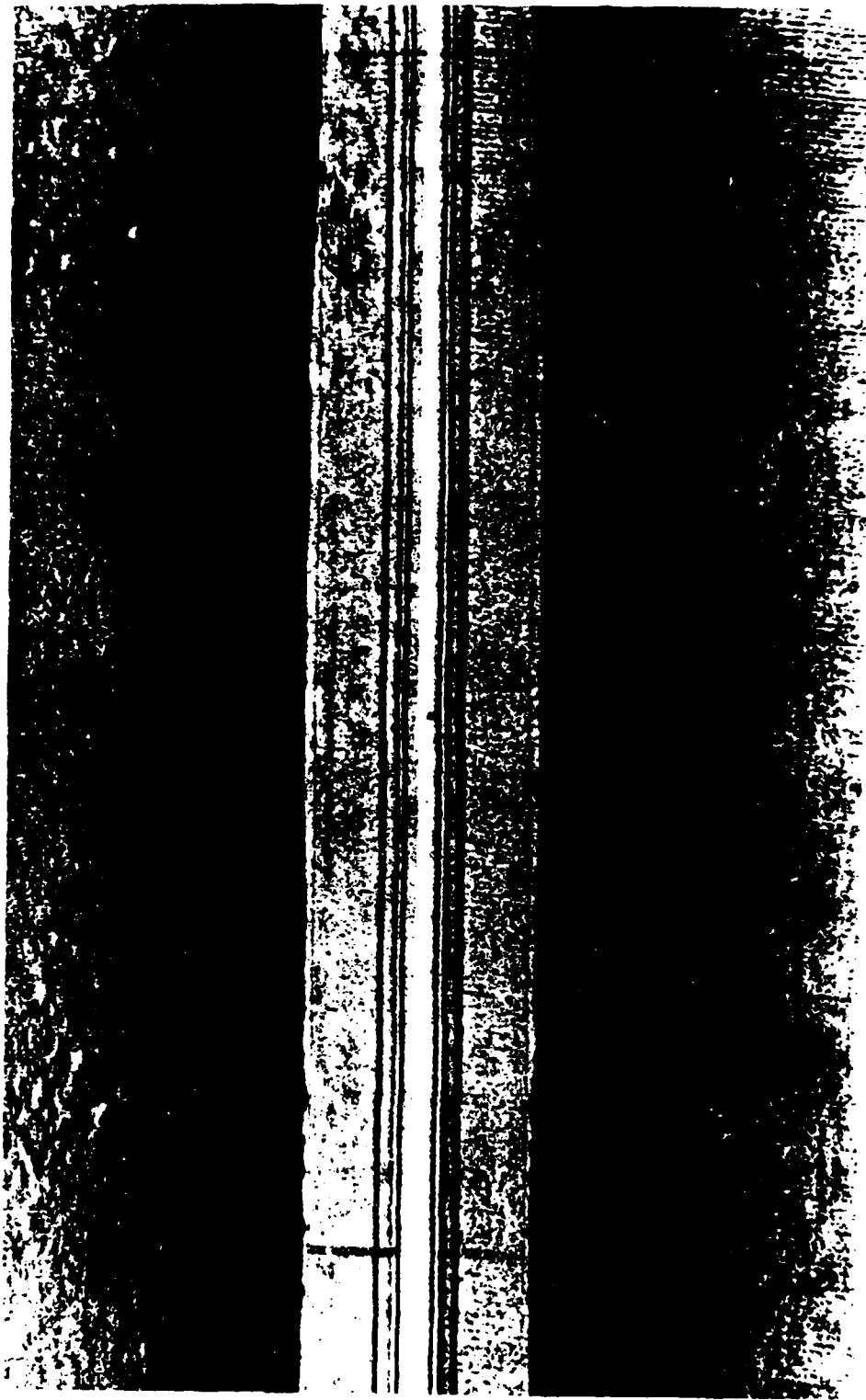


Figure 3.A.2-42 Type "3d" side scan sonar record, MBDS (October, 1985) Dredged material deposit with less intense acoustic reflection indicating margins of dredged material deposits.

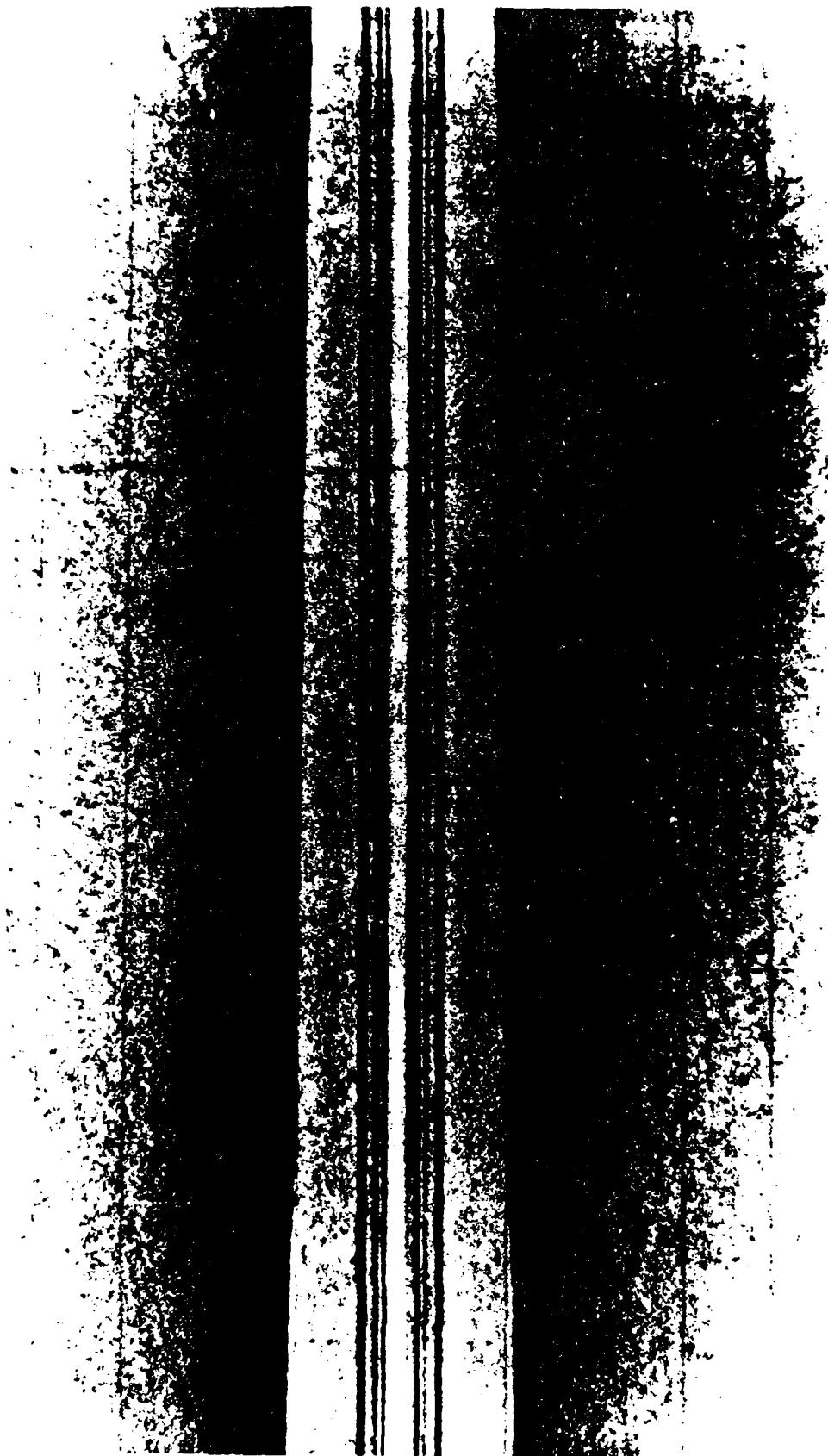


Figure 3.A.2-43 Type "4" side scan sonar record, MBDS (October, 1985) Soft, natural silt bottom with low acoustic reflectance.



Figure 3.A.2-44 REMOTS image from northeast quadrant of MBDS (Station 1-15) showing a dense mat of polychaete tubes overlying coarse sediments.



Figure 3.A.2-45 REMOTS image from natural silt bottom at MBDS  
(Station 18-17)

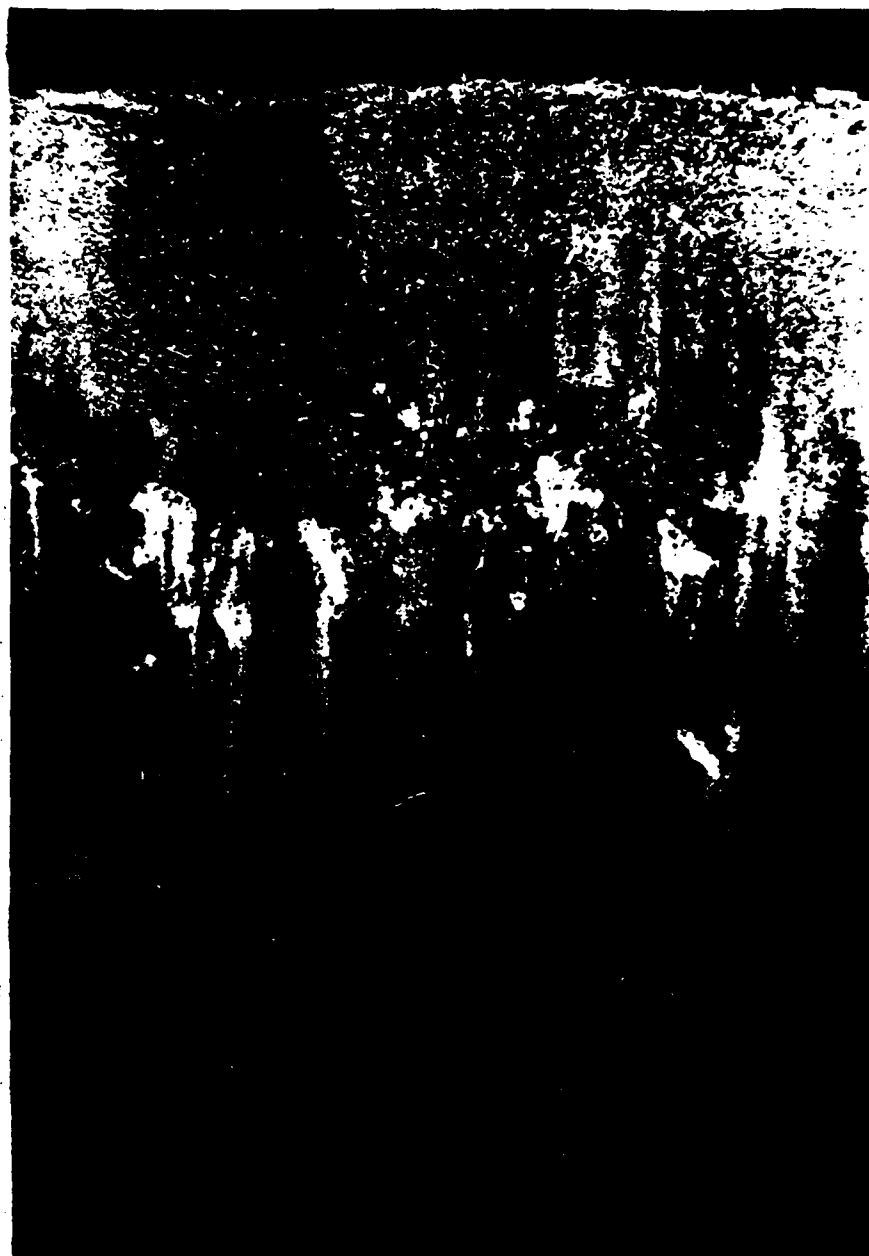


Figure 3.A.2-46 REMOTS image from dredged material deposited at MBDS (Station 11-07) showing very low reflectance (black) material at depth covered by oxidized sediments

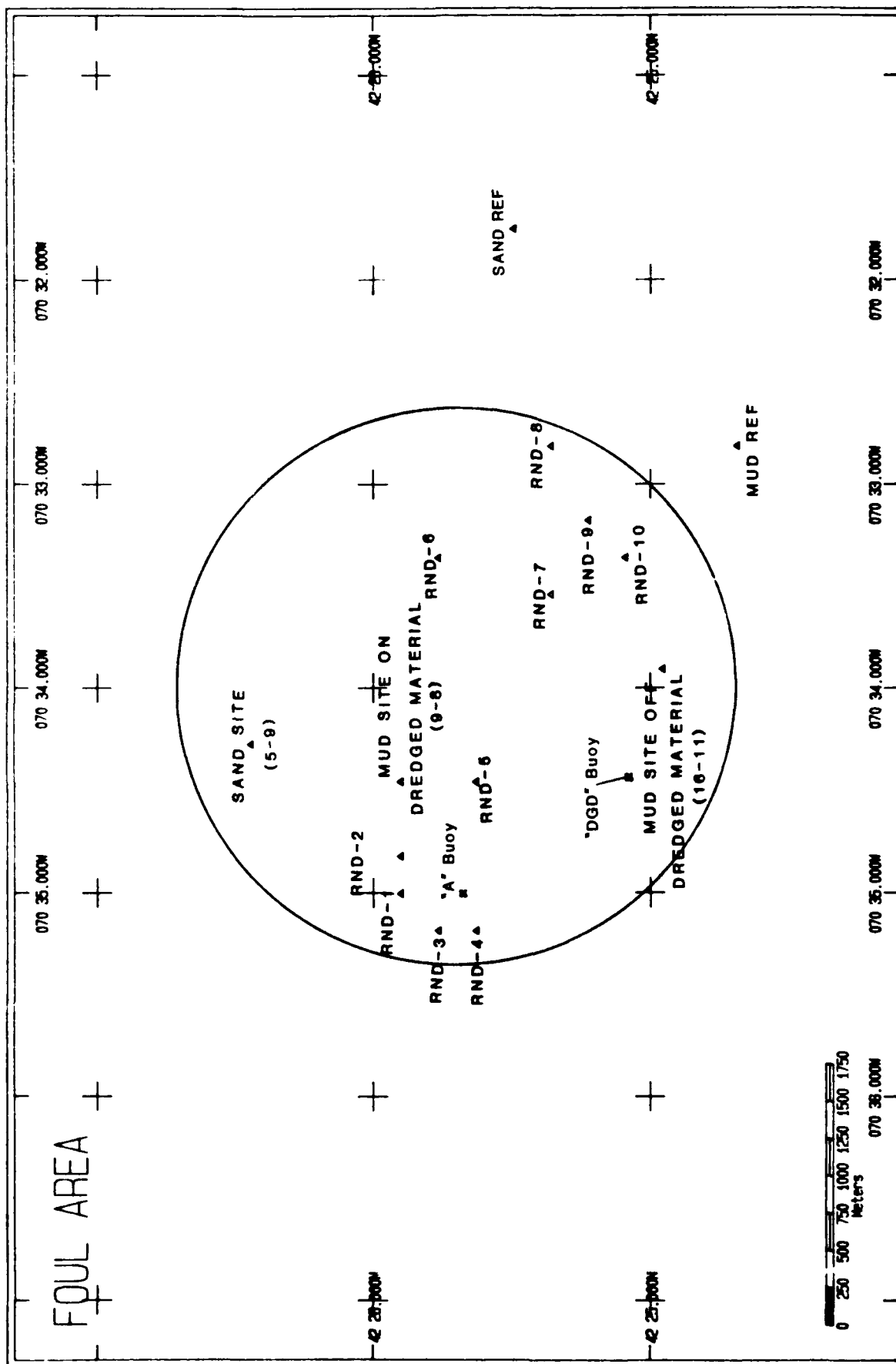
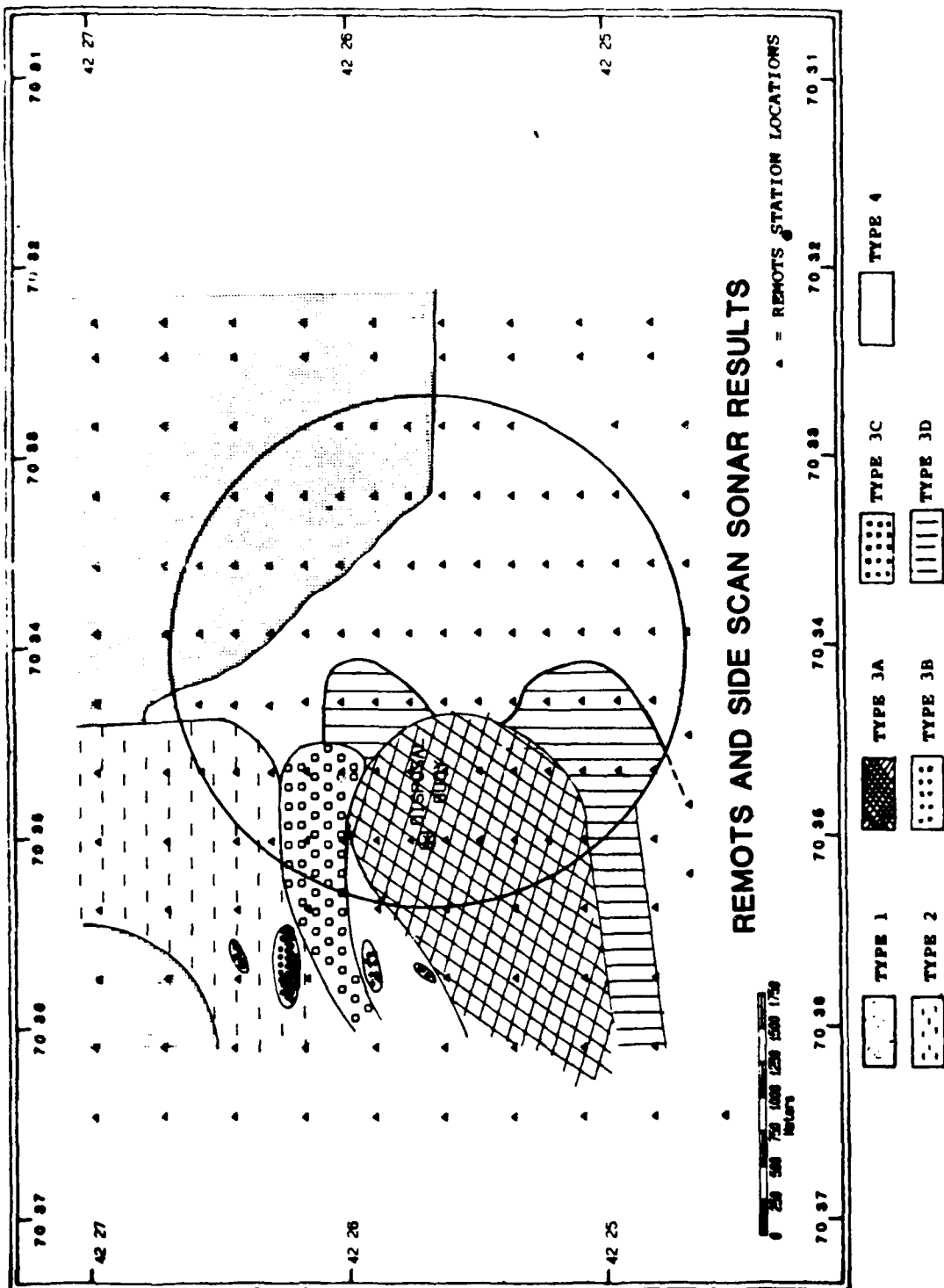
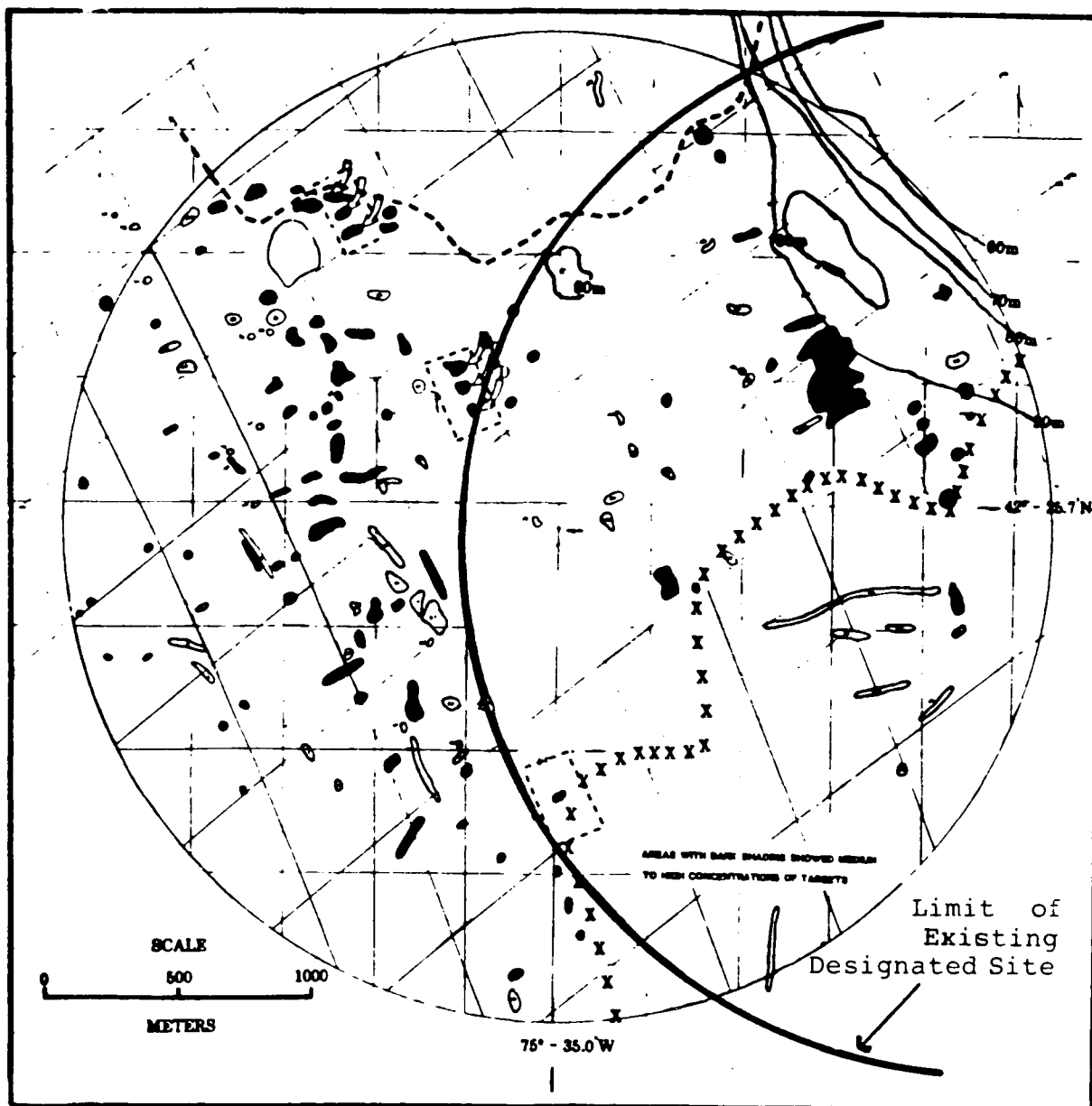


Figure 3.A.2-47 Location of sediment sampling stations at MBDS





**Figure 3.A.2-4E** Distribution of sediment facies at MBDS as determined from side scan sonar and REMOTS surveys. (See section I.2.4 of report for detailed description of sediment types.)




- : southern boundary of uniform bottom containing a large number of hard targets.
- xxxxx : northern boundary of uniform bottom containing a few dredged material deposits.
-  : areas of medium to high densities of targets.

Figure 3.A.2-49 Analysis of side scan sonar survey in the vicinity of MBDS indicating locations of high reflectance

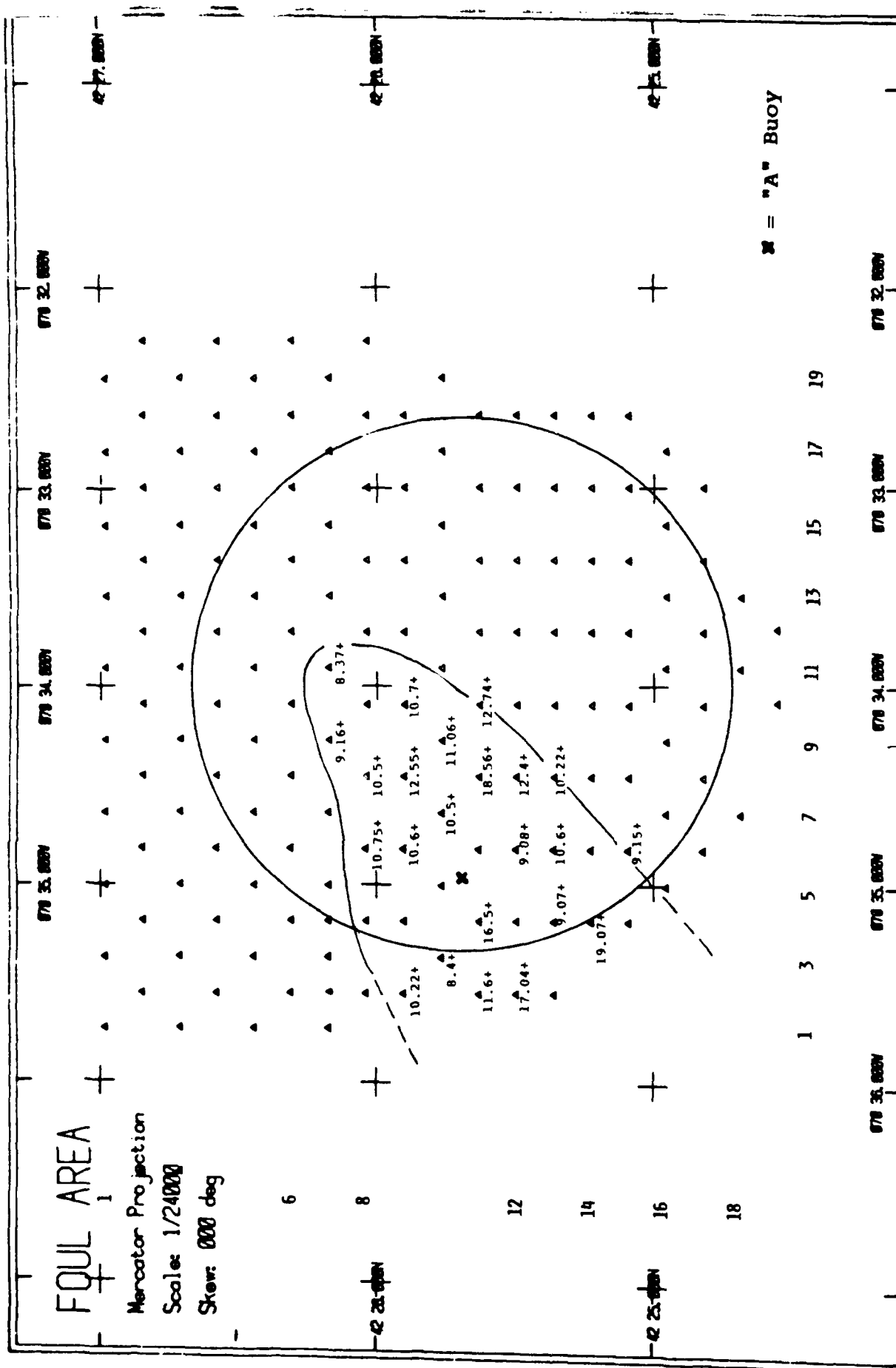
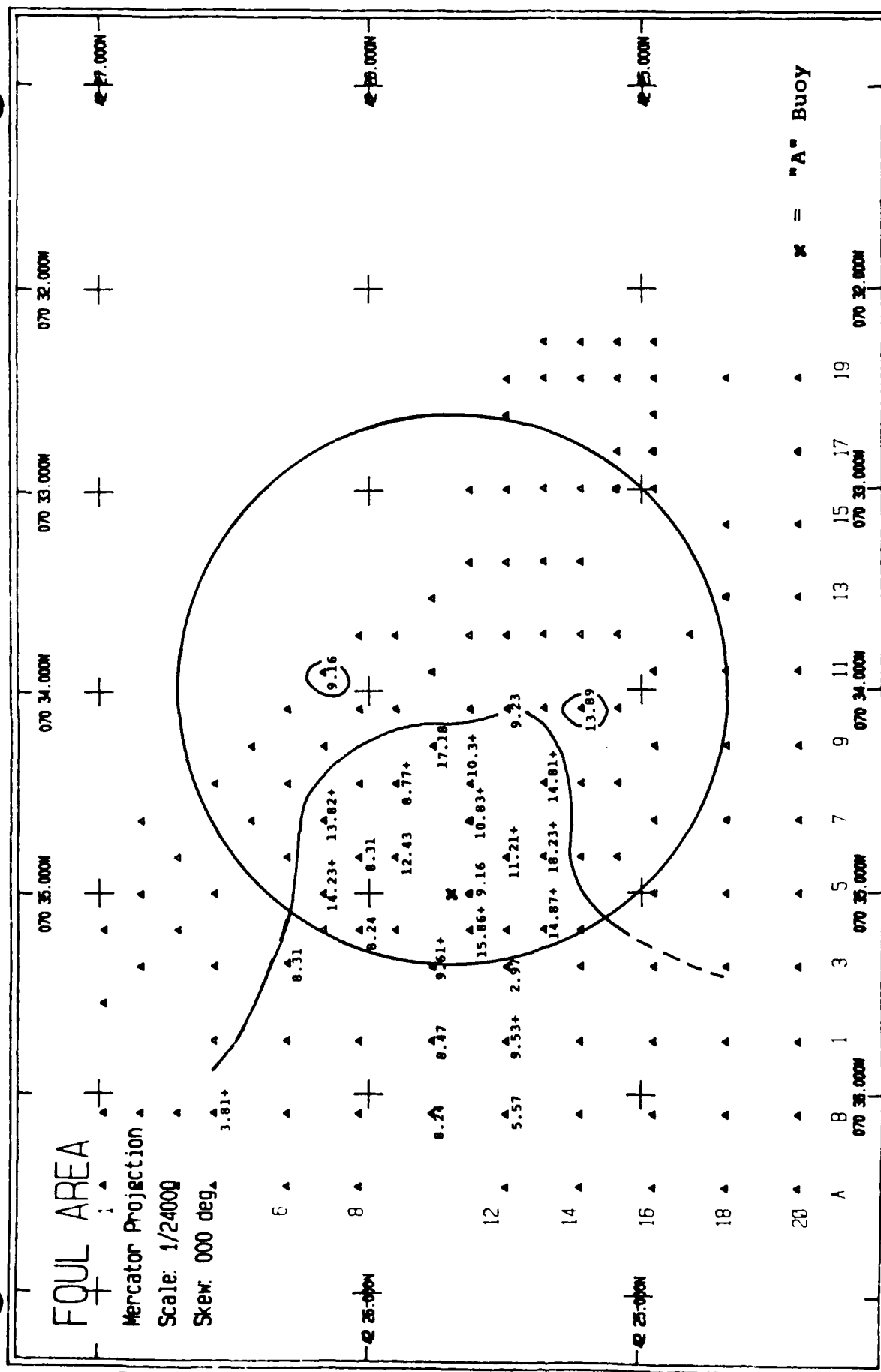


Figure 3.A.2-50 The apparent distribution and thickness (cm) of dredged material at MBDS in June 1985, based on REMOTS data. (+ indicates dredged material thicker than the REMOTS prism penetration depth) (Contour indicates limit of dredged material)



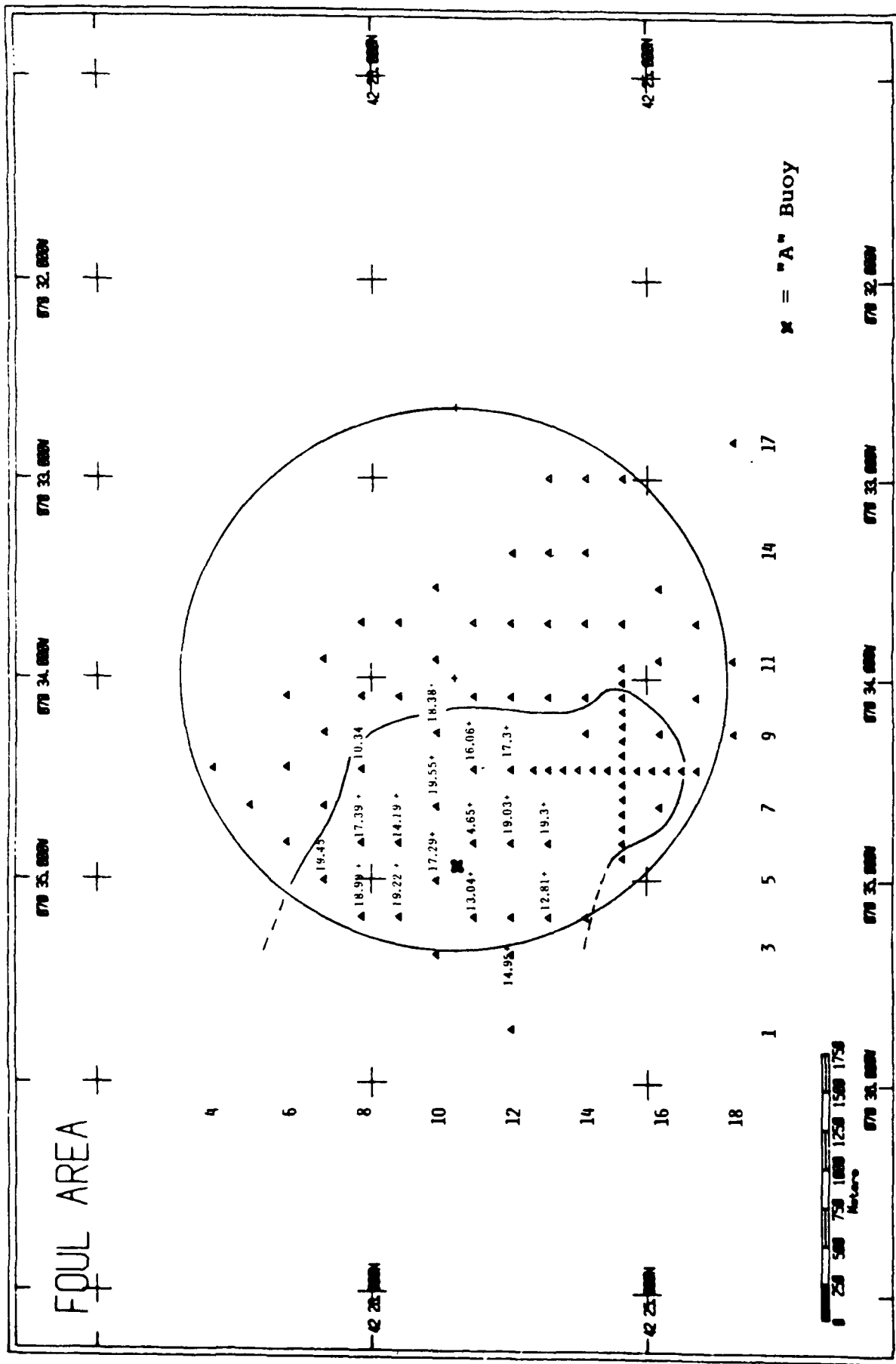


Figure 3.A.2-52 The apparent distribution and thickness (cm) of dredged material at MBDS in January 1986, based on REMOTS data. (+ indicates dredged material thicker than the REMOTS prism penetration depth) (Contour indicates limit of dredged material)



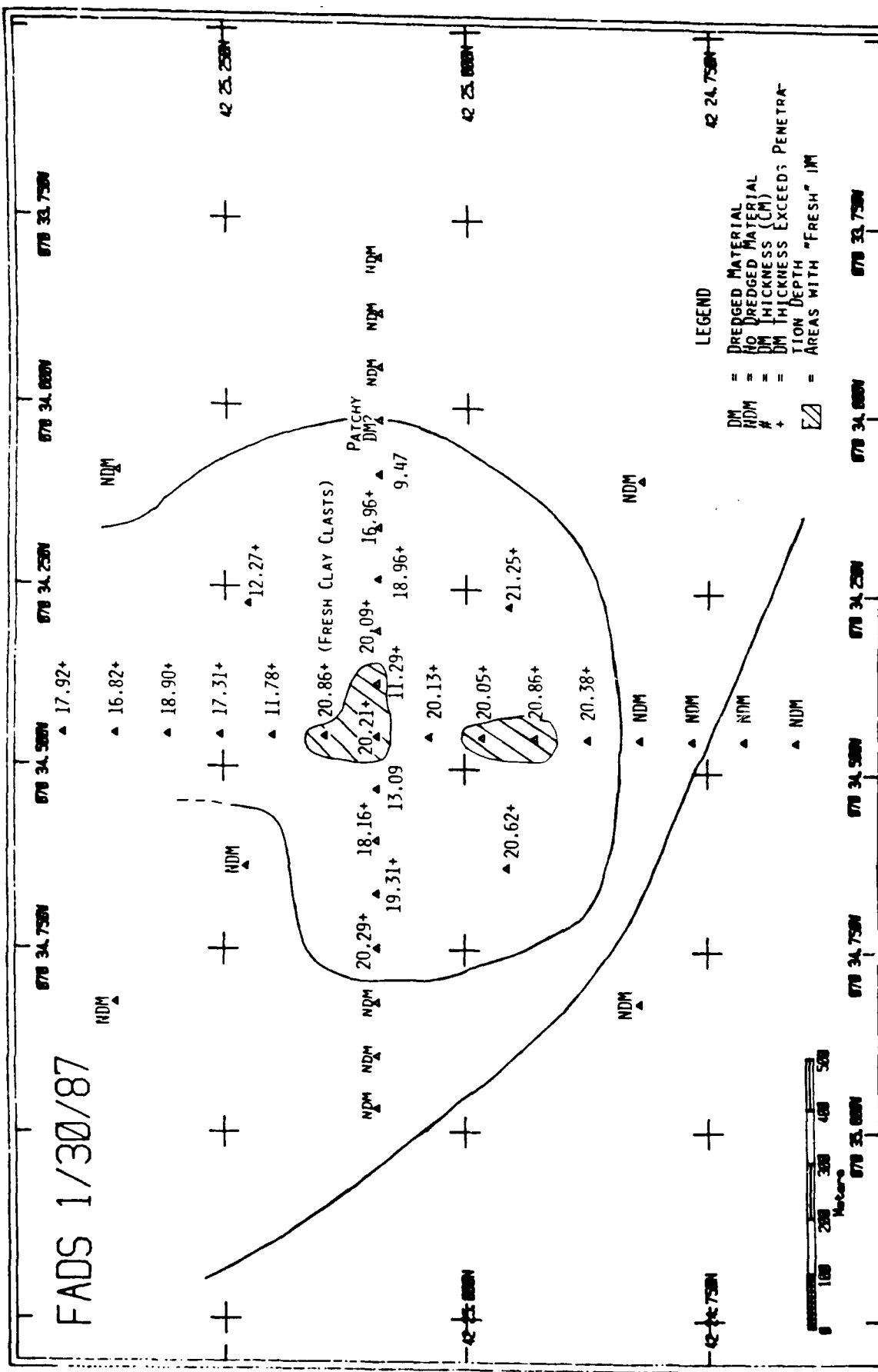


Figure 3.A.2-54 The apparent distribution and thickness (cm) of dredged material in the vicinity of the "DGD" disposal buoy at MBDS in January 1987, based on REMOTS data. (+ indicates dredged material thicker than the REMOTS prism penetration depth) (Contour indicates limit of dredged material) (hatched areas represent indications of recently deposited dredged material)

Table 3.A. 1-1

Summary Of Climatic Conditions, Boston, Massachusetts  
(U.S. Department Of Commerce, 1979)

| Month | Mean<br>Temp °F | Mean<br>Precipitation<br>In Inches | Wind                 |           |                         |
|-------|-----------------|------------------------------------|----------------------|-----------|-------------------------|
|       |                 |                                    | Mean<br>Speed m.p.h. | Direction | Maximum<br>Speed m.p.h. |
| J     | 29.2            | 3.69                               | 14.2                 | NW        | 61                      |
| F     | 30.4            | 3.54                               | 14.1                 | WNW       | 61                      |
| M     | 38.1            | 4.01                               | 13.9                 | NW        | 60                      |
| A     | 48.6            | 3.49                               | 13.3                 | WNW       | 52                      |
| M     | 58.6            | 3.47                               | 12.2                 | SW        | 50                      |
| J     | 68.0            | 3.19                               | 11.4                 | SW        | 40                      |
| J     | 73.3            | 2.74                               | 10.8                 | SW        | 46                      |
| A     | 71.3            | 3.46                               | 10.7                 | SW        | 45                      |
| S     | 64.5            | 3.16                               | 11.2                 | SW        | 57                      |
| O     | 55.4            | 3.02                               | 12.1                 | SW        | 45                      |
| N     | 45.2            | 4.51                               | 12.9                 | SW        | 54                      |
| D     | 33.0            | 4.24                               | 13.8                 | WNW       | 49                      |
| YR    | 51.3 (MEAN)     | 42.52 (TOTAL)                      | 12.6 (MEAN)          | SW (MEAN) | 61 (MAX)                |
|       |                 |                                    |                      |           | NE (MAX)                |



Table 3.A. 2-1  
Temperature And Salinity Data Obtained At The "Massachusetts Bay Foul Area" (Gilbert, 1975)

| Station #<br>Depth (m) | December 1973 |      | April 1974 |      | July 1974 |      | October 1974 |      |
|------------------------|---------------|------|------------|------|-----------|------|--------------|------|
|                        | T°C           | S ‰  | T°C        | S ‰  | T°C       | S ‰  | T°C          | S ‰  |
| 1-S                    | 6.3           | 31.5 | 5.0        | 31.5 | 20.0      | 33.0 | 11.4         | 32.0 |
| 1-30                   | 6.3           | 32.0 | 4.6        | 31.5 | 10.4      | 33.0 | 9.7          | 32.0 |
| 1-60                   | 6.9           | 32.5 | 4.7        | 32.5 | 9.2       | 33.5 | 8.7          | 32.0 |
| 1-80                   | 7.3           | 32.5 | 4.6        | 32.0 | 7.1       | 34.5 | 9.2          | 32.0 |
| 2-S                    | 6.8           | 31.5 | 5.1        | 32.0 | 20.5      | 33.0 | 11.6         | 31.5 |
| 2-30                   | 6.8           | 33.5 | 4.4        | 31.5 | 9.4       | 35.0 | 10.6         | 32.0 |
| 2-60                   | 6.9           | 32.0 | 4.5        | 31.5 | 8.2       | 34.0 | 8.2          | 32.0 |
| 2-80                   | 7.3           | 32.0 | 4.7        | 32.0 | 6.7       | 34.0 | 8.5          | 32.0 |
| 3-S                    | 7.1           | 32.0 | 4.6        | 31.5 | 21.5      | 33.5 | 11.4         | 33.0 |
| 3-30                   | 6.7           | 32.0 | 4.6        | 31.0 | 8.9       | 34.0 | 11.2         | 32.0 |
| 3-60                   | 7.6           | 32.5 | 4.7        | 31.0 | 8.1       | 34.0 | 8.5          | 33.5 |
| 3-80                   | 7.6           | 32.5 | 4.7        | 32.0 | 6.4       | 34.0 | 8.3          | 33.0 |
| 4-S                    | 7.1           | 31.8 | 5.8        | 32.5 | 20.8      | 32.5 | 11.3         | 32.5 |
| 4-30                   | 7.1           | 32.2 | 4.4        | 33.5 | 10.3      | 34.0 | 10.9         | 33.0 |
| 4-60                   | 7.8           | 32.0 | 4.2        | 34.0 | 7.3       | 34.0 | 8.5          | 32.0 |
| 4-80                   | 7.6           | 32.0 | 4.5        | 33.5 | 6.5       | 35.0 | 8.4          | 32.5 |
| 5-S                    | 7.0           | 32.5 | 6.1        | 31.5 | 21.5      | 34.5 | 11.2         | 31.5 |
| 5-30                   | 7.0           | 32.5 | 4.6        | 34.5 | 13.6      | 34.0 | 10.7         | 32.0 |
| 5-60                   | 7.1           | 32.5 | 4.7        | 34.5 | 8.2       | 36.0 | 8.8          | 33.0 |
| 5-80                   | 7.6           | 33.0 | 4.6        | 31.5 | 6.4       | 34.5 | 9.1          | 32.0 |
| 6-S                    | 7.3           | 31.8 | 6.4        | 32.0 | 20.9      | 34.5 | 11.2         | 32.0 |
| 6-30                   | 7.1           | 33.0 | 4.5        | 32.5 | 10.0      | 35.0 | 11.1         | 32.0 |
| 6-60                   | 7.6           | 32.0 | 4.2        | 31.5 | 8.8       | 34.5 | 8.3          | 32.5 |
| 6-80                   | 7.5           | 32.0 | 4.6        | 32.0 | 7.2       | 35.5 | 8.2          | 32.0 |
| Mean                   |               |      |            |      |           |      |              |      |
| -S                     | 6.9           | 31.8 | 5.5        | 31.8 | 20.8      | 33.5 | 11.3         | 32.1 |
| 30                     | 6.8           | 32.5 | 4.5        | 32.4 | 10.4      | 34.1 | 10.7         | 32.1 |
| 60                     | 7.3           | 32.2 | 4.5        | 32.5 | 8.3       | 34.3 | 8.5          | 32.5 |
| 80                     | 7.5           | 32.3 | 4.6        | 32.1 | 6.7       | 34.5 | 8.6          | 32.2 |
| Total                  | 7.1           | 32.2 | 4.7        | 32.2 | 11.5      | 34.1 | 9.7          | 32.2 |

Table 3.A. 2-2

Summary of Current Statistics for 1974  
(Gilbert, 1975)

| Location<br>In Water<br>Column         | <u>January</u> | <u>April</u> | <u>June</u> | <u>July<br/>August</u> | <u>September</u> | <u>October</u> |
|--|----------------|--------------|-------------|------------------------|------------------|----------------|
| Upper<br>Mean Speed<br>(cm/sec)        | 9              | 12           | *           | 10                     | *                | 10             |
| Middle<br>Mean Speed<br>(cm/sec)       | 8              | *            | 9           | 6                      | *                | 7              |
| Lower<br>Mean Speed<br>(cm/sec)        | 4              | *            | 4           | *                      | 5                | 5              |
| Upper<br>Maximum<br>Speed<br>(cm/sec)  | 21             | 44           | *           | 30                     | *                | 28             |
| Middle<br>Maximum<br>Speed<br>(cm/sec) | 20             | *            | 26          | 19                     | *                | 22             |
| Lower<br>Maximum<br>speed<br>(cm/sec)  | 15             | *            | 17          | *                      | 15               | 17             |

\*No data coverage

Upper = 15.2m  
 Middle = 61.0m  
 Lower = 84.2m

These values are all relative to Mean Low Water (MLW). (The upper current meter was moved to a depth of 30.5m after the initial deployment.)

Table 3.A. 2-3

Easterly Storms in Massachusetts Bay  
(Bohlen, 1981)

| <u>Date</u>        | <u>FASTEST MILE</u>            |                  | Observed<br>Change In<br>Sea Level<br>In Boston<br>Harbor (m) |
|--------------------|--------------------------------|------------------|---|
|                    | Maximum<br>Wind<br>Speed (mph) | <u>Direction</u> |   |
| November 23, 1920  | 59                             | NE               |   |
| April 9, 1935      | 63                             | NE               |   |
| November 17, 1935  | 60                             | NE               |   |
| November 5, 1939   | 62                             | NE               |   |
| September 14, 1944 | 72                             | NE               |   |
| November 30, 1944  | 66                             | NE               | 2.8   |
| November 29, 1945  | 68                             | NE               |   |
| March 3, 1947      | 73                             | NE               |   |
| November 7, 1953   | 67                             | NE               |   |
| April 8, 1956      | 58                             | ENE              | 2.6   |
| February 4, 1961   | 49                             | ENE              |   |
| September 21, 1961 | 45                             | NE               |   |
| September 28, 1962 | 47                             | NE               |   |
| December 24, 1966  | 47                             | NE               |   |
| May 25, 1967       | 50                             | NE               | 2.7   |
| November 12, 1968  | 54                             | NE               |   |
| November 8, 1972   | 48                             | NE               |   |
| March 22, 1977     | 60                             | NE               |   |
| May 9, 1977        | 44                             | NE               |   |
| February 6, 1978   | 61                             | NE               |   |
| January 25, 1979   | 45                             | E                |   |
| October 25, 1980   | 48                             | SE               |   |

Table 3.A.2-4

Annual Occurrence Of Wave Height Equalled Or Exceeded (Percent)  
In Northern Massachusetts Bay  
(From Raytheon, 1974)

| <u>Direction</u>  | Wave Height                                     |  |   |   |
|-------------------|---|--|---|---|
|                   | 12 Feet<br>(3.7 meters)<br>SSMO*<br><u>Data</u> | 10 Feet<br>(3.0 meters)<br>SSMO<br><u>Data</u> | 8 Feet<br>(2.4 meters)<br>SSMO<br><u>Data</u> | 6 Feet<br>(1.8 meters)<br>SSMO<br><u>Data</u> |
| N                 | 0.0   | 0.0  | 0.001   | 0.009   |
| NE                | 0.176   | 0.355  | 0.709   | 1.673   |
| E                 | 0.334   | 0.490  | 0.723   | 1.669   |
| SE                | 0.032   | 0.078  | 0.149   | 0.706   |
| S                 | 0.008   | 0.035  | 0.142   | 0.49  |
| SW                | 0.002   | 0.01   | 0.05  | 0.30  |
| W                 | 0.001   | 0.005  | 0.027   | 0.167   |
| NW                | 0.0   | 0.0  | 0.03  | 0.026   |
| All<br>Directions | 0.553   | 0.973  | 1.831   | 5.04  |

\* -- Summary of Synoptic Meteorological Observations (US Naval Weather Service Command).

**Table 3.A. 2-5**

Grain size parameters of sediments sampled from  
the Massachusetts Bay Disposal Site  
at station locations shown in Figure I.2-50

**"MUD" REFERENCE STATION**

| DATE           | MEAN<br>GRAIN SIZE | % SAND<br>OR COARSER | % SILT<br>OR FINER |
|----------------|--------------------|----------------------|--------------------|
| June 1985      | .011               | 2                    | 98                 |
|                | .010               | 5                    | 95                 |
|                | .015               | 3                    | 97                 |
|                | .013               | 3                    | 97                 |
|                | .010               | 3                    | 97                 |
|                | <u>.017</u>        | <u>2</u>             | <u>98</u>          |
| Mean           | .013               | 3                    | 97                 |
| September 1985 | .018               | 1                    | 99                 |
|                | .016               | 1                    | 99                 |
|                | <u>.013</u>        | <u>1</u>             | <u>99</u>          |
|                | .016               | 1                    | 99                 |
| January 1986   | .012               | 1                    | 99                 |
|                | .009               | 1                    | 99                 |
|                | <u>.008</u>        | <u>1</u>             | <u>99</u>          |
|                | .010               | 1                    | 99                 |

**"SAND" REFERENCE STATION**

| DATE           | MEAN<br>GRAIN SIZE | % SAND<br>OR COARSER | % SILT<br>OR FINER |
|----------------|--------------------|----------------------|--------------------|
| September 1985 | 1.96               | 95                   | 5                  |
|                | 1.19               | 96                   | 4                  |
|                | <u>0.58</u>        | <u>92</u>            | <u>8</u>           |
|                | 1.24               | 94                   | 6                  |
| January 1986   | 0.43               | 82                   | 18                 |
|                | 1.92               | 85                   | 15                 |
|                | <u>0.42</u>        | <u>80</u>            | <u>20</u>          |
|                | 0.92               | 82                   | 18                 |

Table 3.A.2-5 (cont.)

NATURAL SILT STATIONS

| DATE           | MEAN<br>GRAIN SIZE | % SAND<br>OR COARSER | % SILT<br>OR FINER |
|----------------|--------------------|----------------------|--------------------|
| September 1985 |                    |                      |                    |
|                | .021               | 2                    | 98                 |
|                | .012               | 1                    | 99                 |
|                | <u>.015</u>        | <u>1</u>             | <u>99</u>          |
|                | .016               | 1                    | 99                 |
| January 1986   |                    |                      |                    |
|                | .016               | 54                   | 46*                |
|                | .010               | 2                    | 98                 |
|                | .009               | 2                    | 98                 |
|                | .010               | 2                    | 98                 |
|                | <u>.009</u>        | <u>2</u>             | <u>98</u>          |
|                | .011               | 12                   | 88                 |

\* Apparent outlier at station north of others and close to change in depth and substrate.

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NATURAL SAND STATION

| DATE           | MEAN<br>GRAIN SIZE | % SAND<br>OR COARSER | % SILT<br>OR FINER |
|----------------|--------------------|----------------------|--------------------|
| September 1985 |                    |                      |                    |
|                | 0.92               | 95                   | 5                  |
|                | 3.68               | 93                   | 7                  |
|                | <u>3.53</u>        | <u>93</u>            | <u>7</u>           |
|                | 2.71               | 94                   | 6                  |

Table 3.A.2-5 (cont.)

DREDGED MATERIAL STATIONS

| DATE           | MEAN<br>GRAIN SIZE | % SAND<br>OR COARSER | % SILT<br>OR FINER |
|----------------|--------------------|----------------------|--------------------|
| September 1985 | .021               | 20                   | 80                 |
|                | .023               | 10                   | 90                 |
|                | <u>.016</u>        | <u>12</u>            | <u>88</u>          |
|                | .020               | 14                   | 86                 |
| January 1986   | .052               | 36                   | 64                 |
|                | .072               | 47                   | 53                 |
|                | .064               | 38                   | 62                 |
|                | .028               | 23                   | 77                 |
|                | <u>.061</u>        | <u>35</u>            | <u>65</u>          |
|                | .092               | 36                   | 64                 |

## B. Chemical Characteristics

### 1. Water Quality

The disposal of dredged material has the potential to impart a chemical signature of the dredged area on the water column, sediment, and biota of the disposal site. The chemical characteristics within the Massachusetts Bay Disposal Site were analyzed by studying selected chemical concentrations within samples of the water column taken at 3 depths during cruises in June and September 1985, and January 1986. Total data recovered represents 340 chemical determinations, raw data are available in SAIC, 1987.

#### a. Dissolved Oxygen

Measurements of water column dissolved oxygen levels represent various biological processes that balance the production and atmospheric dissolution of oxygen with metabolic consumption. Photic depth and seasonal variations alter these processes and ultimately impart spatial and temporal fluctuations in water column concentrations. In general levels below 6.0 ppm would be of concern, with EPA water quality criteria (EPA, 1976) at 5.0 ppm. Recent NED sampling (SAIC, 1987) is in agreement with various historical investigations that describe concentrations in the vicinity of MBDS (Gilbert, 1975; Frankel and Pearce, 1974; Riser and Jankowskie, 1974).

The levels of water column dissolved oxygen at MBDS were sampled at three depths in each of three seasons and exhibited typical variations for an open water environment. The lowest oxygen concentrations recorded were 7.8 ppm in June for near bottom water column and 7.9 ppm in September for surface concentrations. The highest of the nine sampling points was 12.3 ppm in September 1985, for the mid-water sample with the depth averaged value of all seasons being 9.5 ppm (Standard Deviation = 1.45). Gilbert (1975) identified a range of 6.82 ppm to 12.88 ppm, averaging (n=79) 9.1 ppm (S.D. = 1.52) in the vicinity of MBDS. The oxygen levels are generally saturated, i.e. at maximum dissolved concentrations based on temperature and salinity (Kester, 1975) or near saturation as in bottom samples for the June (79% saturated) and February (89% saturated) samples.

#### b. pH

The measurement of pH in the water column is the determination of the hydrogen ion activity representing the basic or acidic characteristics of the sample as governed by the seawater carbonate system. Seawater pH concentrations of 6.5-8.5 are generally acceptable (Thurston et. al, 1979) and within the range of EPA (1976) marine aquatic life criteria. Sampling in support of this site designation document identified a pH range at MBDS between 7.4 and 8.0, for three seasons and three depth strata, and averaged (n=9) 7.81 (S.D.=0.282). Metcalf and Eddy (1984) and Gilbert (1975) found similar pH values in the vicinity of MBDS, the latter identifying a pH range of 7.32 to 8.2, averaging (n=80) 7.87 (S.D=0.16).



TABLE 3B1

Average of all Water Chemistry Data Points from June and September 1986 and January 1987, MBDS (Surface, mid-depth and bottom averages incorporated instrument detection limits as whole values)

| Parameter              | EPA Criteria<br>Acute (Chronic) | Average | Standard<br>Deviation | Number of<br>Samples |
|------------------------|---------------------------------|---------|-----------------------|----------------------|
| PH                     | 6.5-8.5                         | 8.0     | 0.282                 | 9                    |
| Dissolved Oxygen, mg/l | 5.0                             | 9.5     | 1.45                  | 9                    |
| Total Phosphorous, ppm | 0.1                             | 0.035   | 0.023                 | 33                   |
| Nitrates, ppm          | -                               | 0.134   | 0.1                   | 30                   |
| Ammonia, ppm           | -                               | 0.28    | 0.08                  | 31                   |
| Cadmium, ppb           | 43 (9.3)                        | <0.2    | -                     | 9                    |
| Chromium, ppb          | 1,100 (50)                      | 0.412   | 0.264                 | 34                   |
| Nickel, ppb            | 75 (8.3)                        | 5.0     | -                     | 12                   |
| Copper, ppb            | 2.9 (2.9)                       | 2.82    | 1.3                   | 29                   |
| Zinc, ppb              | 95 (86)                         | <20     | -                     | 36                   |
| Arsenic, ppb           | 69 (36)                         | 2.80    | 1.235                 | 32                   |
| Mercury, ppb           | 2.1 (0.025)                     | 1.35    | 0.82                  | 33                   |
| Lead, ppb              | 140 (5.6)                       | 1.77    | 0.34                  | 30                   |
| PAH, ppb               | 300                             | <20     | -                     | 3                    |
| PCB, ppb               | 10 (0.03)                       | 0.012   | 0.022                 | 10                   |

### c. Nutrients

Nitrogen and phosphorous compounds are essential nutrients that are metabolized by primary producers (e.g. plankton, algae) in photosynthetic processes. It is this primary production that forms the lowest trophic level of marine food web. Excess nutrients can cause eutrophication (over-enrichment) in closed systems and imbalance population dominances in open water areas. Frankel and Pearce (1973) described nitrate as the limiting nutrient in Massachusetts Bay. Water column analyses of nutrients (ammonia, nitrates and phosphorous) were obtained in June and September 1985 and January 1986 from surface, mid-water (50m) and bottom (99m filtered and unfiltered). Nutrient concentrations varied seasonally with highest concentration in the winter.

Ammonia is a nitrogenous compound common in the water column as a result of biological degradation of organic matter. The toxicity of ammonia is influenced by the pH, temperature, and salinity of its solution. Highly alkaline conditions necessary to render low concentrations of ammonia ( $\text{NH}_3$ ) toxic to biota typically are not present in the marine environment because of the carbonate buffering system of seawater, and therefore ammonia water quality criteria are pH and temperature dependent (EPA, 1987).

MBDS water column ammonia concentrations ranged from a low of 0.18 ppm ( $n=3$ ,  $\text{S.D.}=0.17$ ) in June 1985 unfiltered surface waters to a high value of 0.46 ppm ( $\text{S.D.}=0.01$ ) from two replicates at 99 meters (unfiltered) in January 1986. The average ammonia concentration from 31 samples from MBDS was 0.28 ppm ( $\text{S.D.}=0.08$ ).

Past nutrient investigations at MBDS exhibit both seasonal and depth dependent concentrations (Gilbert, 1975), varying with blooms of phytoplankton. The 1973-1974 ammonia data ( $n=79$ ) in the vicinity of MBDS showed ammonia concentrations varying from 0.022 to 0.112 ppm with an average value of 0.045 ppm ( $\text{S.D.}=0.018$ ). During a July 1974 disposal operation of sediments from Boston Harbor, ammonia concentrations ranged from 0.046 ppm to 0.127 ppm in the water column (Gilbert, 1975). Both values are lower than the recent NED averages. These values are indicative of the state of biotic (e.g. phytoplankton) activity and uptake of nitrogenous compounds, as well as nitrogen inputs to the system.

Nitrate concentrations in seawater are also affected by photosynthetic processes (ie protein synthesis). Higher temperatures and associated biotic metabolism could account for the general seasonal trends of low spring/summer concentrations of nitrogen. EPA Water Quality criteria do not exist for nitrates in seawater since it is recognized that toxic effect concentrations could rarely occur in the natural environment (EPA, 1976).

The 30 samples of nitrates at MBDS showed a low concentration in unfiltered surface water of June of 0.01 ppm ( $n=3$ ,  $\text{S.D.}=0.014$ ) to a high

concentration of 0.28 ppm ( $n=3$ ,  $S.D.=0.005$ ) in unfiltered bottom waters in September of 1985. The average nitrate concentration was 0.134 ppm ( $S.D.=0.100$ ) from the 30 samples. These results are slightly higher than earlier studies (Gilbert, 1975) which ranged from a high of 0.256 ppm and a low of  $<0.1$  ppm. The average concentration in the vicinity of MBDS ( $n=80$ ) in 1973-1974 (Gilbert, 1975) was 0.105 ppm ( $S.D.=0.073$ ).

Phosphorous occurs in two different forms in the marine environment. Elemental phosphorous, a toxic substance, regulated by an EPA Water Quality Criteria for marine continuous discharge concentrations of 0.1 ppm. Phosphate phosphorous is a natural compound that is nutritive to primary productivity. Although no phosphate EPA criteria exist (EPA, 1987), this nutrient often is the causative agent in eutrophication (Thurston, et. al., 1979). Analyses performed by NED detect total phosphorous concentrations, but as described below, were well below even the elemental phosphorous criteria.

The lowest occurrence of total phosphorous in the MBDS water column was in June 1985 surface waters (unfiltered). Total phosphorous values were below instrument detection limits ( $<0.01$  ppm) for all three replicates. The highest concentrations occurred in January 1986 mid-water column unfiltered samples of 0.083 ppm ( $n=3$ ,  $S.D.=0.042$ ), also below EPA elemented phosphorous criteria. The average total phosphorous water column concentration was 0.035 ppm ( $S.D.=0.023$ ) from 33 samples. This value is higher, but within the range of previous studies (Gilbert, 1975) that found an average concentration of 0.026 ppm ( $S.D.=0.015$ ) from 80 water column samples that ranged from 0.001 to 0.061 ppm.

#### d. Turbidity

Turbidity affects the depth of light penetration and therefore primary productivity in the water column. Particulate material suspended in the water column contributes to turbidity. Although not equivalent, turbidity is often measured by concentrations of suspended solids in grams/liter. There are no EPA Water Quality Criteria for suspended solids in marine or estuarine waters (EPA, 1987). The 1973-1974 suspended solids concentrations at MBDS were reported (Gilbert, 1975) as ranging from a low of  $<0.1$  mg silica/liter in 30 meters of water for October 1974 and a high of 11.2 mg silica/liter in 86 meters (bottom) for December 1973. The average concentration for 79 analyses was 1.912 mg silica/liter ( $S.D.=1.7$ ). These values exhibited increases during a 1974 disposal operation of 1.1 (60 meters) to 19.3 (30 meters) mg silica/liters with an average of 10.0 mg silica/liter ( $n=4$ ,  $S.D.=8.5$ ).

#### e. Metals

Metals in solution such as copper (Cu), iron (Fe), and Zinc (Zn) are essential elements for biochemical processes, where cadmium (Cd), mercury (Hg), chromium (Cr), and lead (Pb) have no established biological functions (Viarengo, 1985). Seawater contains varying concentrations of

essential and non-essential metals that could be considered contaminants in elevated concentrations. The water column at MBDS was sampled (3 replicates) in three seasons at three depths for cadmium, chromium, nickel, copper, zinc, arsenic, mercury, and lead using methods described in Plumb (1981). These metals are typically of concern in dredged material.

#### Cadmium

Cadmium is a non-essential element with a potential toxicity to marine biota in elevated concentrations. It has the potential to bio-concentrate in biota and is commonly found in wastes from electroplating plants and dye, textile and chemical industries. EPA (1987) sets a marine water quality acute (1 hour average) concentration criteria at 43 ppb and a chronic (4 day average) criteria at 9.3 ppb.

Cadmium was analyzed in the MBDS water column in January with concentrations below the analytical detection limits of 0.2 ppb (unfiltered) and 0.5 ppb (filtered). EPA (1976) reports average seawater cadmium concentrations of 0.15 ppb; Gilbert (1975) reported MBDS 1973-1974 water column cadmium concentrations ranging from a low of 0.03 ppb in July 1974 at 30 meters to a high of 1.0 ppb in December 1973 surface waters, with an average concentration of 0.295 ppb ( $n=77$ ,  $S.D.=0.231$ ).

#### Chromium

Chromium, although abundant in the earth's crust, is usually found in very low concentration in marine waters. Chromium is commonly used in industrial processes (salts) and for corrosion control (chromate compounds) in cooling waters. EPA (1976) reports below detectable ( $< 0.1$  ppb) natural seawater concentrations and recommends a criteria (hexavalent) of 50 ppb (chronic) and 1,100 ppb acute levels (EPA, 1987 and EPA, 1985).

Twenty-four (24) of the 34 chromium analyses performed by NED were below detection limits which ranged from 0.3 to 1.5 ppb. Equating the chromium detection limits (e.g.  $<0.3=0.3$  ppb) yields an average water column value of 1.1 ppb ( $S.D.=0.64$ ). These ranged from a low of  $<0.37$  ( $n=3$ ,  $S.D.=0.06$ ) for surface water in January 1986 to a high of 2.5 ppb ( $n=3$ ,  $S.D.=0$ ) in June 1985 surface waters. These values are well below EPA criteria and above the range of previous (1973-1974) MBDS sampling (Gilbert, 1975) which showed a low chromium value of  $<0.05$  ppb in April at various depths and a high of 1.1 ppb in October surface waters. The average concentration reported was 0.41 ppb ( $n=76$ ,  $S.D.=0.264$ ).

#### Nickel

Nickel is discharged into the marine environment from ore leachate, industrial processes and alloy corrosion. Nickel is found in seawater in the 5-7 ppb range (EPA, 1976). Nickel water quality criteria are 75 ppb for acute concentrations and 8.3 ppb of chronic concentrations.

The 1985-1986 NED sampling program revealed a nickel water column concentration averaging (with a 5 ppb detection limit) 5 ppb (S.D.=0) from 12 samples. The maximum concentration detected was 5 ppb (n=6, S.D.=0) from the bottom water samples, filtered and unfiltered. This value is below the criteria and reflective of natural seawater concentrations. The 1973-1974 samples taken by Gilbert (1975) were similar with a lowest detection of 0.2 ppb found in October 1974 at 76 meters and a high value of 6.5 ppb in December 1973 at 60 meters. The average concentration for all depths/seasons was 2.83 ppb (S.D.=1.54) from 79 replicates.

#### Copper

Copper is an essential trace element required for chlorophyll synthesis in plants and hemoglobin formation in some animals. Copper may be present in the environment naturally or as a result of industrial use or use as a biological control. Natural levels of seawater copper are approximately 3 ppb (EPA, 1976). EPA (1987) water quality criteria indicate 2.9 ppb marine chronic and acute concentrations.

The 1985-1986 NED sampling found copper as low as <1.4 ppb in January 1986 bottom samples and as high as 2.7 ppb (n=3, S.D. = 0.45) in January surface waters. The average water column copper concentration (equating values to detection limits) at MBDS was 2.82 ppb (S.D. = 1.3) from 29 samples. This is slightly below EPA (1987) criteria, actual values would be lower due to equating instrument detection limits to whole value, but in general these data agree with earlier studies. The 1973-1974 studies (Gilbert, 1985) found the average copper concentration in the water column from the vicinity of MBDS to be 2.3 ppb (S.D. = 1.35) from 80 samples. The maximum recorded concentration was 7.0 ppb from surface waters in October 1974 and a minimum of 0.3 ppb from 60 meters in April 1974.

#### Zinc

Zinc is an essential trace metal that occurs in the environment primarily as a result of industrial applications and corrosion control processes of brass and iron. Zinc is reported (EPA, 1976) to occur, at a maximum, in seawater at 10 ppb. EPA water quality criteria (EPA, 1987) are 95 ppb for acute toxicity and 86 ppb for chronic toxicity.

The 1985-1986 NED sampling indicated zinc was below the 20 ppb instrument detection limit for all 36 samples. This is lower than the previous studies that measured zinc at MBDS in 1973-1974 (Gilbert, 1975) as having a maximum concentration of 69 ppb at 60 meters during October 1974 and a minimum of 2 ppb in bottom water during the April 1974 sampling. The average concentration was 21.9 ppb (S.D. = 13.8) for 65 samples.

## Arsenic

Arsenic is ubiquitously present in the environment in pentavalent and trivalent forms, inorganic forms of the latter are more toxic than the former. Typical seawater concentrations of arsenic are 2-3 ppb. Arsenic is also discharged into the environment as an industrial by product and from insecticide applications (EPA, 1976). The EPA (1987) marine water quality criteria recommends chronic discharge limits at 36 ppb and acute limits at 69 ppb.

At the MBDS, 29 of 32 analyses were below instrument detection limits of 2-3 ppb. The January 1986 midwater sample contained an average arsenic concentration of 6.4 ppb ( $n=3$ , S.D. = 0.61). Equating the instrument detection limit to a measured value, the average seawater concentration of arsenic at MBDS was 2.80 ppb ( $n=32$ , S.D. = 1.235). This value is within the natural range for arsenic in seawater.

## Mercury

Mercury is biologically a nonessential element. Mercury has been widely used in the environment as a germicidal or fungicidal agent. EPA (1976) reports seawater to contain 0.03 to 0.2 ppb of mercury. EPA (1987) water quality criteria describe an acute concentration criteria of 2.1 ppb and a chronic criteria of 0.025 ppb. Twenty-four of the 33 samples taken at MBDS were below the instrument detection limits of 0.5 to 2.0 ppb. In January, 1986 all nine replicates exhibited the presence of mercury at all three depths (surface, middle, and bottom), averaging 2.43 ppb (S.D. = 0.56). Equating detection limits to whole values reveals an overall water column mercury average of 1.35 ppb ( $n=33$ , S.D. = 0.82). This is below the acute concentration criteria, (2.1 ppb) but above the 0.025 chronic concentration criteria, but given the high instrument detection limits (above chronic criteria), the summary statistics are misleading. Mercury can be termed variable in concentration, at MBDS with elevated levels (2.43 ppb) detected in January.

## Lead

Lead occurs naturally in the environment and as a result of industrial, mine or smelter discharges and runoff of fuel additives. The marine water quality criteria is set at 140 ppb acute and 5.6 ppb chronic (EPA, 1987).

At MBDS, 27 of the 30 lead water samples were below detection limits of 1.4 to 2.0 ppb. The three replicates in January 1987 analyzed lead in the 1.7 to 3.0 ppb range. Equating detection limits to whole values, lead averages 1.77 ppb (S.D. = 0.34) at MBDS. This agrees with earlier studies Gilbert (1975) that found a maximum lead value of 14 ppb at 60 meters in July 1974 and a minimum value of <0.1 ppb at surface waters in October 1974. The average 1972-1973 lead value was 2.3 ppb (S.D. = 2.71) from 79 samples.

## Summary

In summary, the water column chemical concentrations of metals at MBDS was found in concentrations below the acute criteria (EPA, 1976) for marine waters.

The only violation of the chronic concentration criteria was for the January 1986 mercury analyses. This showed elevated mercury throughout the water column averaging 2.43 ppb (S.D. = 0.56) with the EPA Marine Chronic Criteria at 0.025 ppb. The remainder of the samples were below detection.

### f. Organics

#### Polycyclic Aromatic Hydrocarbons

Polycyclic (or Polynuclear) Aromatic Hydrocarbons (PAH) is a generalized term for a large group of petroleum compounds. They are hydrophobic organic compounds that have a high affinity for organic matter and fine grained sediments. The presence of PAHs in the environment is the result of petroleum spills, runoff, and combustion, as well as biotic and abiotic degradation in the environment. The EPA (1987) marine acute water quality criteria listed 300 ppb as the lowest observed effect level (L.O.E.L.) for Polynuclear Aromatic Hydrocarbons, while listing this effect level, the EPA identifies that there is insufficient data to develop criteria. Unfiltered bottom water samples from MBDS in June 1985 showed a concentration of PAH less than detectable at 20 ppb. Due to their hydrophobicity, the compounds would be associated more with sediments than in solution.

#### Polychlorinated Biphenyl Compounds

Polychlorinated Biphenyls (PCB) are a group of man-made organic compounds, isomers of which have varying toxicity to biota (McFarland, 1986). These compounds are chemically stable, non-flamable, hydrophobic, highly dielectric and have a high boiling point. These same qualities make this compound environmentally persistent. The manufacture of PCB was banned in 1977 in recognition of the environmental persistence and toxic potential of PCB.

From 1929 to 1977 PCBs were produced for use in electric transformers, flame retardants, hydraulic fluids, lubricants, inks and other industrial uses. Various pathways of runoff and disposal of PCB introduce this chemical into the marine environment, often associated with fine particulates, and potentially available for biological uptake. The EPA (1987) water quality criteria for chronic PCB concentrations is 0.03 ppb with the acute concentration criteria established at 10 ppb. PCB is not normally found in seawater since it is a man-made synthetic.

The 1985-1986 NED sampling program at MBDS measured PCB in both dissolved and particulate associated concentrations in bottom water

samples. The dissolved concentrations were 0.006 ppb in June 1985, 0.075 ppb in September 1985 and 0.11; <0.006; <0.006 ppb in January 1986. The September 1985 sample and one replicate from January 1986 were above the EPA chronic criteria, but below the acute level of 10 ppb. The particulate associated PCB was <0.005 ppb in June 1985; 0.007 ppb in September 1985 and 0.005; 0.006; and 0.006 ppb in January 1986, all below EPA criteria. Equating instrument detection limits to whole values gives an average particulate and dissolved bottom seawater concentration of PCB at MBDS of 0.012 ppb (S.D. = 0.022) from 10 samples below the 0.03 ppb chronic criteria.

#### Summary

The water column organic chemical contamination at MBDS exhibits low PAH concentration and occasional PCB concentrations above chronic criteria, but below acute levels. The average PCB seawater concentration is 0.012 ppb, below the 0.03 ppb chronic criteria.

#### 3.B.2. Sediment Chemistry

Disposal of dredged materials from urban harbors often imparts a chemical signature on the substrate that is different from the ambient conditions of the disposal site. This chemical signature is representative of the pollutant input to the harbors that are dredged. Industrial discharges, wastewater treatment systems, and non-point source runoff all contribute chemicals in solution and adsorbed to solid particles that ultimately reside in the sediments on harbor bottoms.

The routine monitoring of disposal sites, and in particular the oceanographic sampling of MBDS in support of this site evaluation document, incorporates various sampling of the chemical concentrations of the substrate within and adjacent to the site. This chemical sampling program allows the site managers to evaluate the spatial distribution of chemical contaminants within the site, the magnitude of this contamination, and the ambient (reference) substrate chemical fluctuations. It also allows a comparison of the accuracy of predisposal testing in predicting the chemical quality of the material that would ultimately reside at the disposal site.

In Chapter 4, a comparison is presented of chemical analyses from all dredged material disposed at MBDS and the predicted annual secondary output from only one of the many wastewater treatment systems in the Massachusetts Bay system. (Secondary treatment removes much greater quantities of contaminants than the currently used primary systems.) It is inherently logical that the material dredged from estuarine basins (channels, anchorages, berths, etc.) will have a chemical composition proportional to the pollutant influx into the estuarine systems. A goal of pollutant abatement efforts in Massachusetts Bay is to modify all treatment systems to at least secondary levels. Realization that dredged material disposal at the MBDS is minor compared to current and even projected treatment



plant inputs to the bay then produces confidence that the ocean disposal alternative afforded users by MBDS allows removal of shoal material, and its associated contaminants, from estuarine navigation areas with minimal disposal impacts. This also allows removal of contaminants from potential storm surge resuspension in the shallow nearshore zone.

Sediment chemistry has previously been analyzed at MBDS by New England Division (1982-3) DAMOS studies (SAIC, 1985). Recent investigations (1985-1987) of sediment chemistry (trace metals and organics) were conducted in support of this site evaluation document. Sampling protocol was established based on previous chemical samples and a series of sediment-water interface profiles (REMOTS photographs) that generated sediment physical characteristics (grain size, boundary roughness, etc.) throughout the site. In June of 1985, an area of fine-grained sediment southeast of MBDS (see Figure 3.B.2-1) was sampled physically, biologically and chemically (3 replicates) to determine if it would be an adequate Reference Site (MBDS-REF). It was determined that this site was representative of the ambient conditions of Stellwagen Basin and unimpacted by disposal of dredged material. In September of 1985 three stations (three replicates (n) each) within MBDS were sampled along with an additional reference area (n=3) northeast of MBDS on sandy substrate (MBDS - SRF or Sand Reference). The three stations within MBDS represent the sediment facies identified, i.e. an unimpacted area in the north and northeastern section of MBDS that is coarse grained with sand (MBDS-NES or North Eastern Sand); an area in southern and eastern MBDS that represents unimpacted fine-grained substrate "off" dredged material (MBDS-OFF) and that area of MBDS impacted by disposal of dredged material (MBDS-ON). Each of these three areas comprise approximately one third of the 3.7 kilometer (two nautical mile) diameter site or, conceptually, a subcircle with approximately a 1.07 kilometer radius. Grain size analysis showed MBDS-SRF and MBDS-NES were composed of coarse-grained material with insufficient fines to analyze for chemical contaminants. In January of 1986 the MBDS-REF station was resampled (n=3) to measure chemical seasonality, along with MBDS-ON (n=3). Additionally in January 1986, five (5) stations were sampled randomly from within MBDS on the dredged material and five (5) random stations off dredged material but within MBDS fine-grained facies were also sampled. This sampling was designed to analyze spatial variability in PCB concentrations and therefore only quantified PCB levels.

In September 1987, nine sites throughout MBDS (see Figure 3.B.2-2) at the site boundary and in various distances from the site, were analyzed for chemistry with particular emphasis on Polycyclic Aromatic Hydrocarbons.

The results of trace metals analyses can be found in Tables 3.B.2-1. Table 3.B.2-2 contains the results of organic analyses and Table 3.B.2-3 contains the random PCB sampling results. The PAH (base/neutrals and acids) results are in Table 3.B.2-4. The analysis methods used in this program conform with EPA guidelines as listed in Table 3.B.2-5.

Each of the sampling stations were analyzed for ammonia, petroleum hydrocarbons, oil and grease, mercury (Hg), lead (Pb), Zinc (Zn), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), % carbon, % hydrogen, % nitrogen, DDT (Dichloro-diphenyl-trichloro-ethane) PAH (Polycyclic Aromatic Hydrocarbon) and polychlorinated bipheyl compounds (PCB).

#### a. Metals

The results of the chemical sampling program for metals are described below. In June, 1985 the MBDS-REF area was sampled to determine its suitability as a chemical reference station. The purpose of sampling in September, 1985 was to compare dredged material MBDS-ON to an area within the MBDS boundary, but off of dredged material (MBDS-OFF). In the January 1986 sampling, concentrations at MBDS-ON were compared to concentrations at the reference area outside of the designated MBDS boundary (MBDS-REF).

Pairwise statistical comparisons between stations (MBDS-ON vs MBDS-OFF and MBDS-ON vs MBDS-REF) for each contaminant were made using the Mann-Whitney U-Test. In addition, the sampling design allowed seasonal comparison to be made at the MBDS-ON station (September, 1985 vs January, 1986) and at the MBDS-REF station (June, 1985 vs January, 1986).

#### Arsenic

Arsenic is released into the marine environment through mineral dissolution, industrial discharges or pesticide applications. Typical sediment concentrations average 6-13 ppm (Barr, 1987). Concentrations of arsenic in dredged material are considered low in the <10 ppm range and high in the >20 ppm range (MDWPC, 1978).

The 1985-1987 sampling program measured arsenic at the reference area (MBDS-REF) to measure 11.3 ppm (S.D. = 2.28) in June of 1985 and 12.1 ppm (S.D. = 1.3) in January of 1986. Arsenic values at the disposal point (MBDS-ON) were 12.0 ppm (S.D. = 4.0) in September 1985 and 13.3 ppm (S.D. = 0.7) in January 1986. The area within MBDS boundary, but off dredged material (MBDS-OFF) averaged 10.0 ppm (S.D. = 1.0) in September 1985. Averaging all values, the arsenic concentration at MBDS was determined to be 11.5 ppm (S.D. = 1.9, n=15). There were no statistical differences in the concentration of arsenic between MBDS-ON and MBDS-REF on January or between MBDS-ON and MBDS-OFF in September, or in seasonal variation.

No other data for background levels of arsenic in the vicinity of MBDS has been identified (NMFS, 1985; Gilbert, 1976). The typical levels reported by Barr (1987) of 6-13 ppm is in good agreement with the 11.5 ppm average for MBDS. Arsenic concentrations within the disposal area were similar to ambient concentrations.

## Cadmium

Cadmium enters the marine environment through deterioration of galvanized pipe or industrial discharges. Gilbert (1976) reported cadmium metal concentrations in the vicinity of MBDS at the 30 cm depth strata (approximately 300-500 years old) as averaging 0.87 ppm (S.D. = 0.54,  $n=10$ ). Barr (1987) indicated typical concentrations in unpolluted estuaries are  $<1$  ppm and moderate levels for dredged material disposal (MDWPC, 1978) range from 5-10 ppm.

MBDS-REF in both June 1985 and January 1986 was below instrument detection limits of  $<3$ -4 ppm. MBDS-ON in September 1985 (the disposal area) showed cadmium levels of 3 and 4 ppm for two replicates and  $<3$  ppm at the third replicate. In January 1985 MBDS-ON samples were below the  $<3$  ppm instrument detection level. The MBDS-OFF September 1985 data were also below the  $<3$  ppm detection limit. Therefore, the cadmium levels within MBDS and at the reference area can be categorized as below instrument detection levels of 3-4 ppm, except for the two replicates, on dredged material that averaged 3.5 ppm (S.D. = 0.71).

Cadmium concentrations were generally below detection. Sampling by the National Marine Fisheries Service (Table AI-I) at a station 10 km (Appendix II- Table AIII) south-southwest of MBDS revealed cadmium levels were 0.27 ppm (S.D. = 0.05,  $n=20$ ) (NMFS, 1985). Gilbert (1976) reported cadmium levels to be highly variable at 32 station, throughout Massachusetts Bay, ranging from 0.09 ppm to 3.59 ppm. In the vicinity of MBDS cadmium levels averaged 0.8 ppm (S.D. = 0.77,  $n=10$ ). Gilbert (1975) reported reference area cadmium levels as 5.8 ppm (surface of substrate), 6.4 ppm (0-5 cm strata) and 2.9 ppm (20-25 cm strata). Within MBDS, surficial cadmium levels were 3.36 ppm (S.D. = 0.59,  $n=5$ ).

Continental shelf cadmium levels (Bothner *et al.*, 1986) were generally lower than the Massachusetts Bay (Gilbert, 1976) values at 0.029 ppm (S.D. = 0.019,  $n=8$ ), well below the detection limits employed at MBDS. Larsen *et al.* identified average cadmium levels in Penobscot Bay as 0.44 ppm; Mystic River Estuary as 0.41 ppm (from Lyons and Fitzgerald, 1980); Branford Harbor, CT as 1.16 (from Lyons and Fitzgerald, 1980); and eastern Long Island Sound as 2.7 ppm (from Greig *et al.*, 1977).

In summary, cadmium levels were below detection limits at MBDS-REF and MBDS-OFF, and were in low concentration on the dredged material mound. Other studies agree with these values as generally indicative of typical Massachusetts Bay levels of cadmium, at the 0-4 ppm levels; with pristine levels in the 0-1 ppm level. MDWPC (1978) classifications would rank all of these values as low or Class I since they are  $<5$  ppm.

## Chromium

Chromium enters the marine system from industrial waste (salts) and from corrosion control (chromate compounds) in cooling waters. Gilbert

(1976) reported chromium trace metal concentrations in the vicinity of MBDS at the 30 cm strata (approximately 300-500 years old) as averaging 46.4 ppm (S.D. = 14.7, n=9). Barr (1987) indicated concentrations of chromium in "clean sediments" as 63-100 ppm and moderate levels for dredged material disposal (MDWPC, 1978) range from 100 to 300 ppm.

MBDS-REF chromium concentrations in June 1985 were 70.3 ppm (S.D. = 2.08, n=3) which were significantly ( $p < 0.05$ ) higher (Mann-Whitney U-test) than the January 1986 average of 64.3 ppm (S.D. = 0.58, n=3). This statistical significance represents the low relative percent variability in replicates (3.0% in June and 0.9% in January), and the 70.3 ppm and 64.3 ppm concentrations are quantitatively similar. In January, 1986 the chromium concentrations at MBDS-ON stations were statistically higher ( $p > 0.05$ ) than the reference samples. MBDS-OFF chromium concentrations were quantitatively similar to the reference area, averaging 72.0 ppm (S.D. = 1.0, n=3). Additionally, MBDS-OFF was not statistically different than MBDS-ON.

The 1982 and 1983 MBDS reference sampling ranged 61-75 ppm. The 1982 reference samples averaged 68.5 ppm (S.D. = 5.4, n=6) and 1983 samples were 70.0 ppm (S.D. = 0, n=2).

The six sampling cruises conducted by NMFS during 1979 to 1982 (NMFS, 1985) averaged 35.2 ppm (S.D. = 8.41, n=20) for chromium from an area approximately 10 kilometers south-southwest of the MBDS-ON station. Gilbert (1976) reported Massachusetts Bay chromium concentration ranging from 3-126 ppm. Stellwagen Basin samples from this study averaged 85.9 ppm (S.D. = 22.0, n=10). Gilbert's (1975) reference station had a 73 ppm chromium surficial concentration, 111 ppm at the 0-5 cm strata and 53 ppm in the 20-25 cm strata.

Bothner *et al.* (1986) identified outer continental shelf levels of 50.9 ppm (S.D. = 11.1, n=8). Larsen *et al.* (1983) identified chromium levels from 12 studies throughout New England as ranging from 16 ppm to 274 ppm.

In summary, the dredged material disposal area at MBDS-ON had elevated chromium concentrations (115 ppm, S.D. = 22.4, n=5) compared to reference values. The statistically elevated MBDS-ON chromium value of 115 ppm falls into the moderate (100-200 ppm) category for dredged material classification. The reference area and the MBDS-OFF area (within MBDS but off dredged material) appears to be unimpacted by disposal, having an average value of 67.3 ppm (S.D. = 3.6, n=6).

#### Copper

Copper enters the marine system from industrial uses and applications as a biological control. Gilbert (1976) identified levels from the pre-industrial sediment strata (300-500 years old) at 30 cm as having an average copper value of 13.1 ppm (S.D. = 6.48, n=10). Barr (1987)

identified typical nearshore concentrations averaging 48 ppm, "clean" estuaries at 10 ppm, and polluted estuaries at 37-225 ppm. The MDWPC (1978) moderate dredged material classification is 200-400 ppm.

MBDS-REF June 1985 copper data averaged 18.0 ppm (S.D. = 1, n=3); which was statistically, significantly lower than (Mann-Whitney U-test,  $p < 0.05$ ) the January 1986 MBDS-REF average of 26.7 ppm (S.D. = 0.57, n=3). Both values are quantitatively similar to the pre-industrial (Gilbert, 1976) range of 5.8 ppm to 26.2 ppm and are probably statistically different because of the low intrastation variability. MBDS-ON copper values ranged from 44 to 95 ppm with a mean of 69.8 ppm (S.D. = 18.6, n=6).

The MBDS-OFF copper concentrations in September were significantly lower (Mann-Whitney U-test,  $P < 0.05$ ) than at MBDS-ON and similar to MBDS-REF, averaging 23.3 ppm (S.D. = 1.53, n=3). The January sampling however revealed that MBDS-ON concentrations were significantly higher than at MBDS-REF.

Copper values from the 1982 NED reference sampling ranged from 17 to 25 ppm, with an average of 20.5 ppm (S.D. = 2.7, n=6). The 1983 NED sampling reported reference values averaging 21.5 ppm (S.D. = 0.71, n=2).

NMFS (1985) sampling program occupied stations 10 kilometers south-southwest of MBDS-ON sampled stations (1979-1982) which averaged 7.78 ppm (S.D. = 1.53, n=20) for copper. Gilbert (1976) identified copper values throughout Massachusetts Bay as ranging from 2.6 to 36.0 ppm, and average values for Stellwagen Basin were 20.3 ppm (S.D. = 7.28, n=10). Gilbert's (1975) Reference Station had a surficial copper concentration of 30 ppm, a 0-5 cm strata average of 49 ppm and 20-25 cm strata copper value of 14 ppm. Bothner *et al.* identified outer continental shelf copper values averaging 11.0 ppm (S.D. = 3.8, n=8). Average Penobscot Bay copper concentrations from 55 stations were 14.1 ppm (Larsen *et al.*, 1983).

In general, copper concentrations at MBDS-REF averaged 22.3 ppm (S.D. = 48, n=6), comparable to other studies of unimpacted areas and to the 300-500 year old sediment strata value of 13.1 ppm (S.D. = 6.48, n=10) reported by Gilbert (1976). The dredged material disposal mound sediment copper concentration was statistically elevated in comparison to the reference area, having a 69.8 ppm (S.D. = 18.6, n=6) average. Copper concentrations at the unimpacted silty substrate within MBDS (MBDS-OFF) were significantly lower than at MBDS-ON and comparable to the reference site, suggesting no impact from disposal activities within the site. All of these values including samples on the dredged material, fall into the low or Class I category of <200 ppm (MDWPC, 1978).

#### Lead

Lead enters the Massachusetts Bay system from industrial, mine or smelter discharge, and from combustion of leaded fuels. Pre-industrial

levels (30 cm strata) in the vicinity of MBDS (Gilbert, 1976) were estimated to be 31.1 ppm (S.D. = 25.3, n=10). Barr (1987) reported average nearshore lead concentrations as 20 ppm and "clean" estuary levels as 37 ppm. The Massachusetts guidelines for dredged material classification (MDWPC, 1978) identify moderate levels of lead in dredged material to range 100 to 200 ppm.

MBDS-REF June 1985 lead concentrations averaged 41.3 ppm (S.D. = 1.15, n=3) and the January 1986 average concentration was 97.0 ppm (S.D. = 3.0, n=3). Statistical analysis (Mann-Whitney U-test) showed the June concentration to be significantly ( $p < 0.05$ ) lower than the January concentrations. The intrastation variabilities do not account for this anomaly, but the material in January still averages in Class I (MDWPC, 1978). MBDS-ON station lead concentrations within the area of dredged material disposal, were not temporally variable (Mann-Whitney U-test) averaging 156.8 ppm (S.D. = 15.5, n=5) for June 1985 and January 1986 samples. Statistically this value is significantly ( $p < 0.05$ ) elevated in comparison with the reference area. MBDS-OFF (the station within MBDS boundary, but unimpacted by disposal) lead values are quantitatively similar to the reference areas, averaging 58.3 ppm (S.D. = 6.5, n=3). The September, 1985 sampling revealed no significant difference in lead concentration between MBDS-ON (151 ppm) and MBDS-OFF (58 ppm). The January 1986 sampling indicated that the lead concentration at MBDS-ON (161 ppm) was significantly higher than at the MBDS-REF station (97 ppm).

The 1982 NED reference sampling lead concentration averaged 37.0 ppm (S.D. = 16.8, n=5). NMFS (1985) sampling 10 kilometers south-southwest of MBDS-ON averaged 20.02 ppm (S.D. = 3.67, n=20). Gilbert (1976) identified lead levels in Massachusetts Bay ranging from 6.0 ppm to 149.0 ppm from 32 stations. Average surficial lead concentrations in the vicinity of MBDS in that study were identified as 59.6 ppm (S.D. = 23.9, n=10). The Gilbert (1975) reference area approximately 2.5 kilometers south-southwest of MBDS contained a surficial lead concentration of 85 ppm; the 0-5 cm strata was 52 ppm and the 20-25 cm strata was 51 ppm. Bothner et al (1986) reported outer continental shelf lead levels (Lydonia Canyon) as averaging 10.2 ppm (S.D. = 1.5, n=8). Larson et al. (1983) reported Penobscot Bay lead levels as averaging 23.5 ppm from 55 stations.

In summary, lead levels are significantly elevated at the disposal area (MBDS-ON), averaging 156.8 ppm (S.D. = 15.5, n=5) as compared to the reference site. The reference sampling results indicate highly variable concentrations with regards to seasonality. The June 1985 MBDS-REF average of 41.3 ppm (S.D. = 1.15, n=3) and September 1985 MBDS-OFF average of 58.3 (S.D. = 6.5, n=3) appear to be unimpacted by dredged material disposal.

The elevated MBDS-REF January 1986 lead concentration of 97.0 ppm (S.D. = 3.0, n=3) is anomalously elevated but within the Massachusetts Bay wide variability identified by Gilbert (1976), which ranged up to 149 ppm 20 kilometers south-southwest of MBDS. Comparing these values to the

MDWPC (1978) classification, the references area and the unimpacted area within MBDS would average Class I, while the dredged material area would fall into the Class II category.

#### Mercury

Mercury enters the marine system as organic and inorganic salts, often bound to organic matter and historically it was used in vessel bottom paints as a biological (fouling) control. Gilbert (1976) reported the 30cm horizon levels in the vicinity of MBDS (i.e. pre-industrial levels from 300-500 years ago) averaged 0.31 ppm (S.D. = 0.35, n=10) and the detection limit of 0.01 ppm was averaged as a whole value when exceeded. Barr (1978) reports average nearshore concentrations of 0.1 to 0.4 ppm.

MBDS mercury values for almost all stations were below instrument detection levels of 0.1 ppm to 0.05 ppm. The only detectable mercury levels determined in the 1985 to 1986 sampling program were in the January 1986 MBDS-ON samples. These were generally at or just above detection limits averaging 0.14 ppm (S.D. = 0.08, n=3). Similar results were obtained in the 1982 sampling by NED.

Gilbert (1986) found mercury throughout Massachusetts Bay to range from below a 0.01 ppm detection limit to 5.5 ppm for 32 sites. That study averaged surficial mercury concentrations in the vicinity of MBDS as 0.21 ppm (S.D. = 0.1, n=10). Gilbert's (1975) reference area measured mercury in the 0-5 cm sediment strata as 1.2 ppm and as 0.32 ppm in the 20-25 cm strata. Bothner *et al.* measured outer continental shelf mercury as averaging 0.02 ppm (S.D. = 0.007, n=8).

In summary, mercury levels within MBDS and at adjacent reference areas were at background levels. MDWPC (1978) classification for dredged material would place all sites in the low or Class I category.

#### Nickel

Nickel is commonly used in industrial processes, herbicides and wood preservatives, or released through lead and copper alloy corrosion. Gilbert (1976) reported levels at the 30 cm sediment strata (300-500 year old strata), these data averaged 29.9 ppm (S.D. = 12.6, n=10). Barr (1987) reported average sediment nickel concentration to be 6-13 ppm. The MDWPC (1978) classification of dredged material indicates 50 to 100 ppm is considered a moderate concentration.

MBDS-REF sediment nickel concentrations averaged 33.3 ppm (S.D. = 1.5, n=3) in June of 1985 and was less than the 24 ppm detection limit in January 1986. MBDS-ON sediment samples had a September 1985 nickel average of 31 ppm (S.D. = 1.0, n=3) while in January 1986 this station had a <24 ppm replicate and replicates of 25 and 26 ppm. MBDS-OFF in September 1985 had all three replicates <24 ppm.

The NMFS (1985) sampling in the vicinity of Stellwagen Basin nickel sediment concentrations averaged 11.04 ppm (S.D. = 2.43, n=20). Gilbert (1976) identified nickel surficial sediment concentrations throughout Massachusetts Bay ranging from 3.7 ppm to 55.9 ppm at 32 stations. In the immediate vicinity of MBDS, surficial concentrations were identified by Gilbert (1976) as 32.8 ppm (S.D. = 12.8, n=10). Gilbert's (1975) reference site had surficial nickel concentrations of 57 ppm, 0-5 cm strata concentrations of 33 ppm and 20-25 cm strata concentrations of 31 ppm. Bothner et al. identified outer continental shelf nickel values that averaged 12.1 ppm (S.D. = 7.1, n=8). Larsen et al. identified nickel levels in Penobscot Bay as averaging 26.1 ppm from 55 stations.

In summary, nickel values at MBDS-REF are within ambient ranges, predominantly below the 24 ppm detection limit. This agrees with pre-industrial (300-500 years ago) sediment levels in Stellwagen Basin vicinity averaging 29.9 ppm (S.D. = 12.6, n=10). MBDS-ON is also at these levels. These results place all nickel data in the MDWPC (1978) low or Class I category.

## Zinc

Zinc enters the marine environment from corrosion of galvanized iron and brass and from industrial discharges. Deeper sediments may release zinc from complexes with Fe and Mn (Barr, 1987). Gilbert (1976) reported zinc values from the 30 cm horizon (300-500 years old) in MBDS vicinity that averaged 128.6 ppm (S.D. = 89.5, n=10). Barr (1987) reported average nearshore concentrations as 55 ppm and "clean" estuary at 38 ppm, in contrast to a "polluted" estuary range of 50-600 ppm. MDWPC (1978) classification of dredged material lists 200-400 ppm as the moderate range.

Statistical analysis identified that there was no significant difference ( $p < 0.05$ ) between sediment zinc concentrations at MBDS-REF in June 1985 and January 1986. The average zinc concentrations at MBDS-REF in 1985-1986 was 102.8 ppm (S.D. = 18.8, n=6). The January analysis revealed MBDS-ON zinc concentrations to be significantly elevated in both seasons in comparison to MBDS-REF. The average MBDS-ON zinc concentration for both September 1985 and January 1986 was 219.7 ppm (S.D. = 42.0, n=6). The MBDS-ON value was statistically higher than MBDS-OFF which averaged 105.0 ppm (S.D. = 2.0, n=3).

The 1982 NED sampling at MBDS reported a reference area zinc sediment concentration averaging 159.8 ppm (S.D. = 36.1, n=6). The 1983 NED reference sites averaged 160 ppm (S.D. = 11.3, n=2). The NMFS (1985) data from an area 10 kilometers south-southwest of MBDS averaged 37.12 ppm (S.D. = 5.49, n=20). Gilbert (1976) reported zinc concentrations throughout Massachusetts Bay as ranging from <9 ppm to 399.7 ppm (the latter in Cape Cod Bay). In MBDS vicinity, surficial sediment concentrations from Gilbert (1976) averaged 154.9 ppm (S.D. = 141.4, n=10). Gilbert (1975) reported reference area surficial zinc concentrations at



173 ppm; 0-5 cm strata at 165 ppm and 30-25 cm strata at 115 ppm. Bothner *et al.* (1986) reported outer continental shelf zinc values that averaged 37.1 ppm (S.D. = 10.2, n=8). Larsen *et al.* (1983) reported Penobscott Bay zinc concentrations to average 78.3 ppm from 55 stations.

In general, zinc concentrations at MBDS reference site are in good agreement with ambient Stellwagen Basin levels (Gilbert, 1976) averaging 102.8 ppm (S.D. = 19.8, n=6). The dredged material area (MBDS-ON) has a statistically significant higher concentration of zinc, averaging 219.7 ppm (S.D. = 42, n=6), than the reference area and the unimpacted area within the disposal boundary (MBDS-OFF). MBDS-ON average concentration would be classified as moderate or Class II (200-400 ppm) according to the dredged material classification guidelines of MDWPC (1978).

#### Summary - Metals

Recent and historical sediment chemistry determinations have identified various areas of Massachusetts Bay as depositional areas for fine-grained particulates emanating throughout the system (Gilbert, 1976). Quiescent deepwater basins, such as Stellwagen Basin, are usually such areas. The 1985-1987 chemical sampling program has identified a reference area (MBDS-REF) that is unimpacted by trace metals from dredged material disposal. The disposal point itself (MBDS-ON) from within MBDS, shows statistically significant elevations in concentrations of chromium, copper, lead and zinc, as compared to the reference area. These metals reflect the most recent dredged material inputs and are generally in the moderate (Cr, Pb, and Zn) to low (As, Cu, Cd, Hg, and Ni) contamination categories of dredged material classification (MDWPC, 1978). The MBDS-OFF area, within MBDS boundary but spatially remote from the dredged material disposal mound, has levels that are comparable to the reference area. Therefore, significant elevations of metal contaminants are restricted to the point of disposal, and not impacting the FAD-OFF or reference areas.

#### b. Organic Chemicals

Carbon (total organic), DDT (Dichloro Diphenyl-Trichloroethane), hydrogen, nitrogen, oil and grease, petroleum hydrocarbons, PAH (Polycyclic Aromatic Hydrocarbons), and PCB (Polychlorinated Biphenyl Compounds) were measured at MBDS during the various sampling cruises (Table 3.B.2-2).

#### Ammonia, Carbon, Hydrogen and Nitrogen

Total organic carbon, hydrogen, nitrogen and ammonia are indicative of the organic state of the substrate. Ammonia concentrations were measured at 189.0 ppm (S.D. = 8.0, n=3) at MBDS-REF in June 1985. Total organic carbon values at MBDS-REF in June 1985 and January 1986 averaged 2.67% (S.D. = 0.06, n=6). MBDS-ON in September 1985 and January 1986 averaged 3.05% (S.D. = 0.26, n=6). MBDS-OFF was similar to MBDS-REF with the average total organic carbon being 2.70% (S.D. = 0.01, n=3). These

values are in good agreement with Boehm et al. (1984) who described total organic carbon within MBDS as 2.75% (S.D. = 0.13, n=5), but elevated in comparison with the rest of Massachusetts Bay values in that study. The Boehm et al. (1984) station 11 kilometers south of MBDS averaged 1.7% (S.D. = 0.12, n=5) and another station 18.5 kilometers southeast of MBDS averaged 0.96% (S.D. = 0.13, n=5). Low carbon to nitrogen ratio's are indicative of the quality of organic matter available for biotic metabolism. MBDS-REF (June 1985 and January 1986) C:N averaged 8.6 (S.D. = 0.08, n=6), lower than MBDS-ON (September 1985 and January 1986) average value of 11.6 (S.D. = 1.4, n=6), but in good agreement with MBDS-OFF (September 1985) C:N of 8.7 (S.D. = 0, n=3). The April 1983 NED reference sampling exhibited similar results with an 8.8 (S.D. = 0, n=2) C:N ratio and the 1982 reference data were intermediate with an average of 10.2 (S.D. = 0.32, n=6).

#### Oil and Grease

Oil and grease determinations are a general measure of biological lipids and mineral (biological and petroleum) hydrocarbons that are soluble in trichloro-trifluoroethane. This is a parent group of organic hydrocarbons. Dredged material is considered as having a moderate contaminant levels of these compounds when composed of 0.5-1.0% (5,000 - 10,000 ppm) oil and grease (MDWPC, 1978).

MBDS-REF oil and grease sediment values in June 1985 and January 1986 averaged 285 ppm (S.D. = 87.0, n=5). Statistical analysis revealed MBDS-ON September 1985 and January 1986 oil and grease to be statistically elevated ( $p < 0.05$ ) in comparison to MBDS-REF. MBDS-ON sediment oil and grease averaged 1763.3 ppm (S.D. = 421.6, n=6). MBDS-OFF, the area within MBDS boundary but off dredged material, was statistically ( $p < 0.05$ ) similar to MBDS-REF having an average of 306 ppm (S.D. = 131, n=3). The April 1983 NED sampling of MBDS had a reference area oil and grease average of 262 ppm (S.D. = 28.3, n=2).

Gilbert (1975) reported a reference area surficial oil and grease concentration of 170 ppm, an anomalously high 0-5 cm strata concentration of 1,070 ppm and a 0-25 cm strata concentration of 880 ppm.

In general, the disposal area is characterized by statistically significant ( $p < 0.05$ ) elevations of oil and grease (avg. = 1763.3 ppm, S.D. = 421.6, n=6) in comparison to the reference area (avg. = 285 ppm, S.D. = 87.0, n=5). The area within MBDS but off dredged material averaged 306 ppm (S.D. = 131, n=3) indicating this area is statistically ( $p < 0.05$ ) similar to the reference site and both are generally unimpacted by disposal of dredged material. All samples from MBDS fall within the low or Class I (MDWPC, 1978) oil and grease classification of  $< 0.5\%$ .

## Petroleum Hydrocarbons

Petroleum hydrocarbons are a subset of oil and grease determinations, specifically those organic compounds of petroleum origin. A majority of sediment oil and grease determinations can be expected to be of petroleum origin in combination with biological lipids.

MBDS-REF petroleum hydrocarbon levels averaged 244.4 ppm (S.D. = 112.9, n=5). MBDS-ON had statistically (Mann-Whitney U Test,  $p < 0.05$ ) a higher average of 1513 ppm (0.15%, S.D. = 302.6, n=6). MBDS-OFF was similar to the reference area at 327 ppm (S.D. = 10, n=3).

The petroleum hydrocarbon levels at the reference area and MBDS-OFF are in good agreement with other data from unimpacted New England areas. Sites in lower Narragansett Bay/Rhode Island Sound had levels reported in the range of 100-300 ppm (Pruell and Quinn, 1985; Wade and Quinn 1979, Boehm and Quinn, 1978). The disposal area is impacted with statistically elevated levels of petroleum hydrocarbons, but, as indicated by the MDWPC (1978) classification of oil and grease, the petroleum hydrocarbon concentrations are quantitatively low.

## PAH

Polycyclic Aromatic Hydrocarbons (PAH) are a measure of the aromatic fraction of the petroleum hydrocarbons. PAH, by definition, are molecules composed of carbon and hydrogen atoms arranged in one or more six-carbon rings. As such, this grouping encompasses a large family of compounds, 16 of which are considered priority pollutants. Concentrations of total PAHs were below detection levels at MBDS-REF in June 1985. In October, 1987, a priority pollutant scan, including base/neutrals and acids (see Table 3B.2-4) was conducted for nine sites across MBDS (see Figure 3.B.2-2). Of the 603 chemical determinations (including 16 priority pollutant PAH), only fluoranthene was detected, at 0.51 ppm at one station (detection limit = 0.33 ppm), the site of most recent disposal. Additionally, at this station, the plasticizer Di-n-butylphthalate was present at 0.44 ppm (detection limit = 0.33 ppm) and Bis (2 ethylehexyl) phthalate at 7.2 ppm (detection limit = 0.33 ppm).

Boehm *et al.* (1984) identified total PAH levels within MBDS as averaging 3.5 ppm (S.D. = 1.0, n=5). At a station 11 kilometers south of MBDS PAH concentrations were 1.5 ppm (S.D. = 0.1, n=5) and 18.5 kilometers southeast of MBDS, PAH levels were recorded at 1.9 ppm (S.D. = 0.1, n=5).

Worldwide, PAH determinations are being conducted as a measure of anthropogenic stress on the marine environment (Smith, 1985). PAH concentrations are directly related to grain size and total organic carbon content of the sediments (Larsen *et al.*, 1986). Johnson and Larsen (1985), identified total PAH concentrations from 49 stations in the Penobscot Bay region of the Gulf of Maine as ranging from 0.286 to 8.784 ppm. Offshore

PAH concentrations from 19 stations in the Gulf of Maine ranged from 0.010 to 0.512 ppm (Larsen et al., 1986) with basin areas (Wilkinson and Jordan) acting as accumulation areas.

Two transport mechanisms for PAH into the marine system are offered by Windsor and Hites (1979) as sediment resuspension and transport and atmospheric transport. Hite (1979) identified total PAH levels ranging from 0.018 ppm for deep ocean sediments to 120 ppm for sediments in Boston Harbor (Charles River vicinity).

That study also identified elevated levels of PAH in Wilkinson Basin, attributing it to the fine particulate settling nature of the basin. This is the same hypothesis Gilbert (1976) put forth on Stellwagen Basin, i.e., metals would be elevated due to the fine particulate "sink" that basin areas represent.

Acey et al. (1987) and Pruell and Quinn (1985) describe di-n-butyl phthalate (DNBP) and di-ethylhexyl phthalates as the predominant molecular forms of Dialkylphthalates, widespread in the environment with annual worldwide production rates of  $5 \times 10^8$  kg/yr. This study also describes embryonic sensitivities to certain phthalates in solution, low toxicities to adult organisms and a biomagnification potential. The impact/importance of the levels reported for dredged materials of MBDS are not known. Biototoxicity tests performed prior to any disposal activity are used as safeguards against DNBP and synergistic effects.

In summary, PAH compounds were not detected in significant levels at the reference station for MBDS in June 1985 or October 1987. Testing of sediment samples on dredged material and at nine different sites throughout MBDS only revealed PAH at the site of recent dredged material disposal, 0.51 ppm of flouranthene. Additionally this site contained 7.64 ppm of phthalate compounds.

#### PCB

Polychlorinated Biphenyls are organic compounds manufactured industrially between 1929 and 1977. Their chemical stability made them an attractive industrial dielectric coolant and lubricant, as well as giving them environmental persistence. There are approximately 210 different chemical isomers that were commercially combined to form "Arochlors", a commercial U.S. trade name. PCB levels in dredged material are considered by DWPC (1978) as moderate in the 0.5 ppm to 1.0 ppm range. Historical levels of sediment PCB would be zero since it is a man made compound.

PCB levels analyzed at MBDS-REF in June 1985 and January 1986 averaged 0.061 ppm (S.D. = 0.062 ppm, n=6) indicating a highly variable (and low) concentration. PCB levels were statistically elevated (ANOVA,  $p < 0.05$ ) on the disposal mound, MBDS-ON in September 1985 and January 1986 averaging 0.784 ppm (S.D. = 0.559, n=6), also highly variable data. Statistically, (ANOVA,  $p < 0.05$ ) the September 1985 samples were higher in

PCB concentrations than the January 1986 sample. Within MBDS but off dredged material (MBDS-OFF) showed similarly variable data to the reference area, although it is quantitatively elevated, averaging 0.336 ppm (S.D. = 0.3745, n=3).

The variability of PCB values have been well documented in other NED studies (SAIC, 1985). A specific question was raised in the course of this program as to whether the PCB levels on dredged material (in the vicinity of MBDS-ON) was statistically elevated in comparison to those levels off dredged material, but within the boundary of MBDS (in the vicinity of MBDS-OFF). Five random samples from each site were analyzed and the non-impacted region of MBDS averaged 0.073 ppm (S.D. = 0.065, n=5), while the area impacted by dredged material averaged 0.414 ppm (S.D. = 0.403, n=5). Statistically, there was not a difference in concentration between the sites ( $p = 0.65$  on log transformed data), because of the high variability (89.0% and 97.3%, respectively).

Gilbert (1976) identified PCB ranges throughout the Mass/Cape Cod Bay System as ranging from <0.00032 ppm to 0.018 ppm from 32 stations. Surficial sediment PCB concentrations reported by Gilbert (1976) in the vicinity of MBDS averaged 0.0061 (S.D. = 0.0052, n=10) also having highly variable (85.2%) data. Gilbert (1975) identified surficial PCB levels at 0.021 ppm; 0-5cm strata 0.030 ppm and the 20-25 cm strata at 0.009 ppm.

Boehm *et al.* identified PCB levels within MBDS as averaging 0.0829 ppm (S.D. = 0.016, n=5); an area 11 kilometers south of MBDS averaging 0.0253 ppm (S.D. = 0.0036, n=5) and an area 18.5 kilometers southeast of MBDS averaging 0.007 ppm (S.D. = 0.0021, n=5).

In summary, PCB levels are highly variable throughout MBDS. Reference levels averaging 0.061 ppm (S.D. = 0.062 ppm, n=6) are indicative of ambient Stellwagen Basin values. The disposal area (MBDS-ON) contained elevated PCB concentrations of 0.784 ppm (S.D. = 0.559, n=6). Sampling to date has not resolved whether there is a statistical difference between MBDS PCB levels on or off dredged material within MBDS, owing to the variability in data. It is quantitatively probable that the 0.414 ppm (S.D. = 0.403, n=5) PCB level on dredged material is elevated in comparison to the 0.073 ppm (S.D. = 0.065, n=5) value off dredged material, but within MBDS. Overall, the reference area and MBDS would be well within the low or Class I MWPC (1978) category. The disposal mound average of 0.414 ppm is also Class I, but its range has one replicate at 1.04 ppm, or Class III value.

#### Summary - Organics

Organic chemical investigations at MBDS indicate elevated organics constituents at the disposal area, but ambient concentrations at the reference sites and in areas within MBDS but off dredged material. Carbon to nitrogen ratios averaged 11.6 (S.D. = 1.4, n=6) for the disposal mound, and 8.6 (S.D. = 0.008, n=6) for the reference site, which was equal to the

unimpacted site within MBDS at 8.7 (S.D. = 0, n=3). Oil and grease levels were low (<0.5%) but statistically ( $p < 0.05$ ) elevated at the disposal area at 1763.3 ppm (S.D. = 421.6, n=6), in comparison with the reference sediment concentration of 285 ppm (S.D. = 87.0, n=5) and the unimpacted area within the site averaging 306 ppm (S.D. = 131, n=3). Petroleum hydrocarbons were also quantitatively low but elevated on the dredged material site at 1513 ppm (S.D. = 302.6, n=6) compared to reference levels of 244.4 ppm (S.D. = 112.9, n=5) and MBDS-OFF of 327 ppm (S.D. = 10, n=3).

PAH (Polycyclic Aromatic Hydrocarbons) compounds were undetectable throughout the study area except for 0.51 ppm of flouranthene at a site of recent disposal. Phthalate compounds, a plasticizer was also detectable here at 7.64 ppm.

PCB (polychlorinated biphenyl) compounds were highly variable in concentration with disposal area values averaging 0.414 ppm (S.D. = 403, n=5) and unimpacted areas within MBDS averaging 0.073 ppm (S.D. = 0.065, n=5). Reference area PCB concentrations reflected the "settling basin" nature of Stellwagen Basin averaging 0.061 ppm (S.D. = 0.062, n=6) quantitatively similar to MBDS-OFF values.

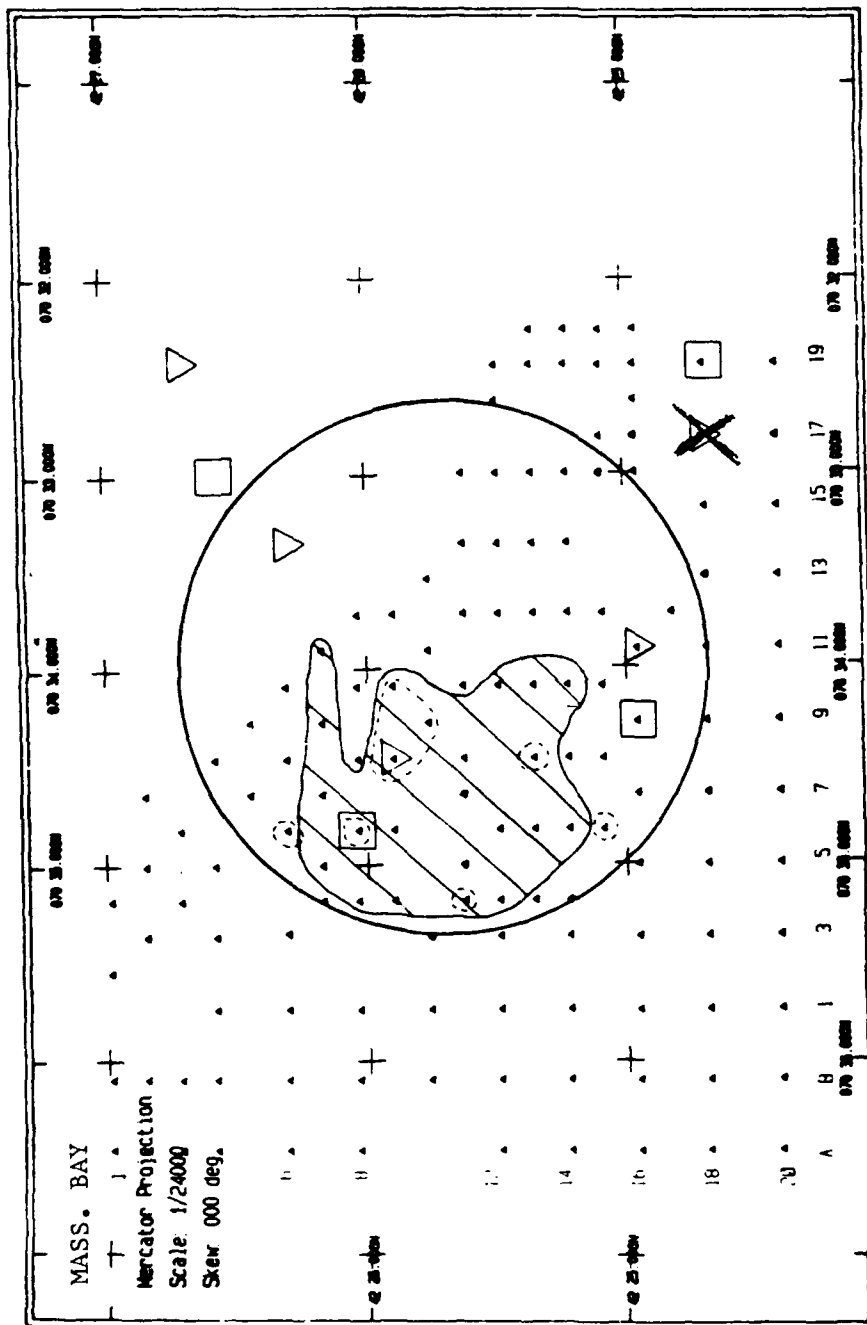


Figure 3.B.2-1 Results of the "quick'look" REMOTS@ survey. The circle encloses the disposal area. The hatched area represents the distribution of observed dredged material and the dashed lines enclose regions exhibiting Stage I seres. Stations identified for box cores (BRAT studies) are enclosed in a square; benthic community sample locations are indicated by a large triangle. The southeast reference site is marked with an x (18-17).

SAIC

Figure 3.B.2-2

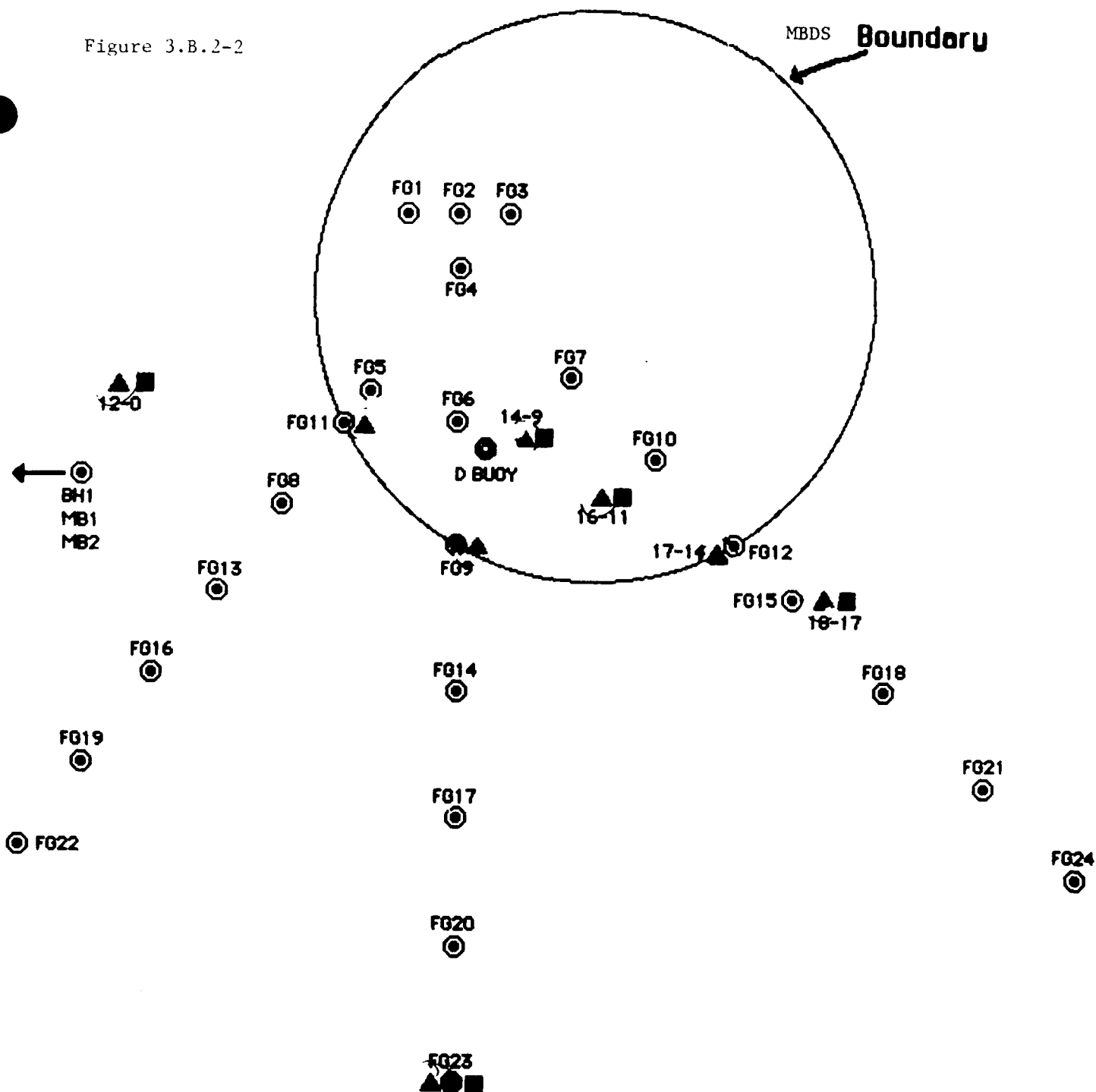




Table 3.B.2-1  
Trace Metal Concentrations in MBDS Sediment Samples  
Concentrations as ppm Dry Weight

|          | MBDS - REF<br>June 1985 | MBDS-REF<br>January 1986 | MBDS-OFF<br>September 1985 | MBDS-ON<br>September 1985 | MBDS-ON<br>September 1985 |
|----------|-------------------------|--------------------------|----------------------------|---------------------------|---------------------------|
| Arsenic  | 11.3 + 2.3 <sup>1</sup> | 12.1 + 1.3               | 10 + 1                     | 12 + 4                    | 13.3 + 0.7                |
| Lead     | 41.3 + 1.2              | 97 + 3                   | 58 + 7                     | 151 <sup>2</sup>          | 161 + 17                  |
| Zinc     | 95.3 + 6                | 110 + 28                 | 105 + 1                    | 233 + 15                  | 206 + 60                  |
| Chromium | 70.3 + 2.1              | 64 + 1                   | 72 + 1                     | 134                       | 102 + 9                   |
| Copper   | 18.0 + 1.0              | 27 + 1                   | 23 + 2                     | 75 + 27                   | 64 + 5                    |
| Cadmium  | <4                      | <3                       | <3                         | 4                         | <3                        |
| Nickel   | 33.3 + 1.5              | <24                      | <24                        | 31 + 1                    | 26                        |
| Mercury  | <0.05                   | N.A.                     | <0.1                       | <0.01                     | N.A.                      |

1 - Mean + standard deviation of 3 analyses.

2 - Mean of duplicate analyses, one replicate an apparent outlier.  
N.A. - Not analyzed.

Table 3.B.2.-2  
Organic Analysis Results of MBDS Sediment Samples  
Concentrations As Dry Weight

|                                   | MBDS - REF<br>June 1985  | MBDS - REF<br>January 1986 | MBDS - OFF<br>September 1985 | MBDS - ON<br>September 1985 | MBDS - ON<br>January 1986 |
|-----------------------------------|--------------------------|----------------------------|------------------------------|-----------------------------|---------------------------|
| Total<br>Carbon, %                | 2.54 ± 0.01 <sup>1</sup> | 2.69 ± 0.09                | 2.70 ± 0.01                  | 3.17 ± 0.36                 | 2.94 ± 0.05               |
| Total<br>Hydrogen, %              | 0.71 ± 0.05              | 0.72 ± 0.02                | 0.67 ± 0.01                  | 0.61 ± 0.06                 | 0.68 ± 0.04               |
| Total<br>Nitrogen, %              | 0.31 ± 0.00              | 0.31 ± 0.02                | 0.30 ± 0.00                  | 0.25 ± 0.03                 | 0.28 ± 0.01               |
| Ammonia, ppm                      | 189 ± 8                  | N.A.                       | N.A.                         | N.A.                        | N.A.                      |
| Oil and<br>Grease, ppm            | 201 <sup>2</sup>         | 341 ± 28                   | 306 ± 131                    | 1960 ± 480                  | 1560 ± 300                |
| Petroleum<br>Hydrocarbons,<br>ppm | 121 <sup>2</sup>         | 327 ± 10                   | 195 ± 55                     | 1640 ± 390                  | 1390 ± 172                |
| PAH, ppm                          | <3                       | N.A.                       | N.A.                         | N.A.                        | N.A.                      |
| PCB, ppb                          | 75 ± 92                  | 48 ± 30                    | 495 <sup>2</sup>             | 1240 ± 400                  | 329 ± 26                  |
| DDT, ppb                          | <1                       | N.A.                       | N.A.                         | N.A.                        | N.A.                      |

See Table 3.B.2-1 for explanation of notes.

Table 3.8.2-3 Total PCB Concentrations In Randomly Selected Sediment  
Samples From MBDS, January 1986

Concentrations As ppb Dry Weight

| <u>Natural Soft Bottom</u>     | <u>On Dredged<br/>Material</u> |
|--------------------------------|--------------------------------|
| 29                             | 66                             |
| 151                            | 54                             |
| 136                            | 490                            |
| 30                             | 1040                           |
| 20                             | 420                            |
| <hr/> 73 $\pm$ 65 <sup>1</sup> | <hr/> 414 $\pm$ 403            |

1 - Mean  $\pm$  Standard Deviation.

Table 3.B.2-4 PAH (Base/Neutrals and Acids)  
Analyses from MBDS and Ambient Areas

(Note: 14-9 is an area of recent deposition of dredged material)

DAMOS - MBDS 1987

| Parameter                        | Detection<br>Limits | FG-23<br>2953 | FG-9<br>2955 | 12-0<br>2958 | FG-11<br>2961 | MBDS-REF<br>18-17 | 17-14<br>2991 | SE<br>3004 | 14-9<br>3008 | 16-11<br>3013 |
|----------------------------------|---------------------|---------------|--------------|--------------|---------------|-------------------|---------------|------------|--------------|---------------|
|                                  | ug/Kg               |               |              |              |               |                   |               |            |              |               |
| Phenol                           | 330                 | ND            | ND           | ND           | ND            | ND                | ND            | ND         | ND           | ND            |
| Bis (2-chloro-<br>oethyl) ether  | 330                 | ND            | ND           | ND           | ND            | ND                | ND            | ND         | ND           | ND            |
| 2-Chlorophenol                   | 330                 | ND            | ND           | ND           | ND            | ND                | ND            | ND         | ND           | ND            |
| 1,3-Dichlorobenzene              | 330                 | ND            | ND           | ND           | ND            | ND                | ND            | ND         | ND           | ND            |
| 1,4-Dichlorobenzene              | 330                 | ND            | ND           | ND           | ND            | ND                | ND            | ND         | ND           | ND            |
| Benzyl alcohol                   | 330                 | ND            | ND           | ND           | ND            | ND                | ND            | ND         | ND           | ND            |
| 1,2-Dichlorobenzene              | 330                 | ND            | ND           | ND           | ND            | ND                | ND            | ND         | ND           | ND            |
| 2-Methylphenol                   | 330                 | ND            | ND           | ND           | ND            | ND                | ND            | ND         | 440          | ND            |
| Bis(2-chloro-<br>isopropyl)ether | 330                 | ND            | ND           | ND           | ND            | ND                | ND            | ND         | 510          | ND            |
| 4-Methylphenol                   | 330                 | ND            | ND           | ND           | ND            | ND                | ND            | ND         | ND           | ND            |
| N-Nitroso-di-n-<br>propylamine   | 330                 | ND            | ND           | ND           | ND            | ND                | ND            | ND         | ND           | ND            |

[illegible]

[illegible]

[illegible]





Table 3.B.2.-5  
BULK SEDIMENT TESTING

| PARAMETER              | METHOD  | DETECTION LIMIT |
|------------------------|---|-----------------|
| Total Organic Carbon   | Total Organic Carbon Analyzer                               | 1.0%            |
| Water                  | Gravimetric   | 1.0%            |
| Volatile Solids        | NED   | 1.0%            |
| Petroleum Hydrocarbons | Freon Extraction, Infrared                                  | 0.01%           |
| Oil & Grease           | Freon Extraction, Infrared                                  | 0.01%           |
| Mercury - Hg           | Acid Permanganate Digestion,<br>Flameless Atomic Absorption | 0.1 ppm         |
| Arsenic - As           | Gaseous Hydride, Atomic<br>Absorption Spect.                | 1.0 ppm         |
| Lead - Pb              | Acid Peroxide Digestion,<br>Atomic Absorption Spect.        | 20.0 ppm        |
| Zinc - Zn              | Acid Peroxide Digestion,<br>Atomic Absorption Spect.        | 20.0 ppm        |
| Cadmium - Cd           | Acid Peroxide Digestion,<br>Atomic Absorption Spect.        | 1.0 ppm         |
| Chromium - Cr          | Acid Peroxide Digestion,<br>Atomic Absorption Spect.        | 20.0 ppm        |
| Copper - Cu            | Acid Peroxide Digestion,<br>Atomic Absorption Spect.        | 20.0 ppm        |
| Nickel - Ni            | Acid Peroxide Digestion,<br>Atomic Absorption Spect.        | 30.0 ppm        |
| Total PCB's            | Extraction, Gas Chromatography                              | 0.05 ppm        |
| Grain Size             | Sieves #4, 10, 40, 200                                      | 0.1%            |

Reference: Plumb, A.H., Jr., 1981. "Procedures for Handling and Chemical Analysis of Sediments and Water Samples," Technical Report EPA/CE-81-1, prepared by Great Lakes Laboratory, State University College at Buffalo, N.Y., for the U.S. Environmental Protection Agency/Corps of Engineers Technical Committee on Criteria for Dredged and Fill Material. Published by the U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg Mississippi.

Bulk sediment metals and PCB data are expressed in ppm or ppb based on dry weight of sample.

### 3.B.2.C Grain Size

Grain size analysis of sediments at MBDS was performed on each biological grab obtained. This allowed for replicate sediment grain size results, as well as identifying reasons for excessive intrastation biological variability, if any was encountered.

The median sediment grain size for 12 samples taken at the reference site (MBDS-REF), in 86.7 meters of water, was 0.013mm (S.D.=0.003). This represents a substrate composed (98%) of medium to fine silt (6-7 phi). The natural bottom station within MBDS, but off any disposed dredged material (MBDS-OFF), in 87.9 meters of water, exhibited a median grain size from 7 samples of 0.012mm (S.D.=0.004). This is also a substrate composed (98%) of medium to fine silt (6-7 phi). The substrate in the dredged material disposal area consisted of sediments representative of the most recent deposition from various New England harbors. The median grain size from the station located on dredged material (MBDS-ON), 85.5 meters deep, was 0.042mm (n=8, S.D.=0.022). This represents a coarse silt substrate (4-4.5 phi). In September 1985, the disposal area had a 14% sand or coarser composition (n=3, S.D.=5.3), while in January 1986, the sand or coarser composition was 35.8% (n=5, S.D.=8.6). This phenomenon can be attributed to microscale sampling variability, bioturbation, or subsequent disposal occurrences, given the quiescent nature of the currents and the consistency of grain size at MBDS-REF and MBDS-OFF.

The sandy area in the shallower (65.1 meters deep) northeast quadrant of the disposal circle (MBDS-NES) had a median grain size of 2.71 mm (n=3, S.D.=1.6). This represents a granular substrate (-1.25 to -1.5 phi). The sand reference (MBDS-SRF) station east of the disposal site boundary in 46 to 66 meters of water, had a median grain size of 1.1mm (n=6, S.D.=0.72). This variable sand/granule area has a very coarse sand composition (0 to -0.25 phi).

Two stations sampled by New England Aquarium (NEA) in 1975 (Gilbert, 1976) had similar depth and grain size distribution as onsite and the reference area at MBDS. These stations, NEA 9 and NEA 12 were respectively located 5.5 km northwest and 6 km south-southwest of the center of MBDS, or approximately 4km outside of the MBDS boundary. Station NEA 9 was in 76.5 meters of water and NEA 12 was in 79.5 meters of water, each having a predominant grain size greater than 5.0 phi. The control station (NEA-6) sampled by New England Aquarium in 1974 (Gilbert, 1975) had a sediment composition of 30% fine sand (4 phi) and 70% silts (greater than 5 phi) for the 20 to 25 cm strata; and 15% 4 phi and 85% greater than 5 phi in the 20 to 25 cm strata. This station was located approximately 3.5 km southwest of the center of MBDS, 1.5 km southwest of the site boundary.

### 3.B.3. Biotic Residues

The uptake of contaminants from the abiotic environment (sediment and water column) into the tissues of indigenous organisms results from trophic (feeding) uptake or biomagnification, and direct contaminant ingestion or passive absorption (bioconcentration). This bioaccumulation of contaminants was measured at MBDS by examining the tissue concentration (residue) of contaminants in various organisms. The results and values are an indication of the ultimate mobility of the contaminants from the disposed dredged material into the biotic environment. The rates and mechanisms of uptake vary differently from species to species and therefore values reported here should only be considered as broadly indicative of contaminant bioavailability to a particular species of a certain feeding mode.

The target species analyzed at MBDS were the result of their presence in sufficient biomass density to allow a reasonably efficient collection. The suite of chemicals analyzed required approximately 15 grams wet weight of tissue for each species at each station. This resulted in a 150-200 grab sample (0.01 m<sup>2</sup> Smith-McIntyre) per station effort to obtain sufficient tissue for analysis. Even this sampling effort failed to produce all samples and replicates optimally desired.

At MBDS the species analyzed at each station were the polychaete Nephtys incisa and the bivalve Astarte spp. (Astarte undata and Astarte crenatus) except for MBDS-ON which did not contain any Astarte sp. Additionally opportunistic samples of shrimp, Pandalus borealis and scallop Placopecten magellanicus were analyzed. Nephtys incisa is a free-burrowing, non-selective deposit feeder that ingests sediment as it moves through the substrate. Astarte sp. burrow to just under the sediment surface and filter feed using short siphons to ingest and expel food items in the overlying water column.

Both can be considered residents of the sampling stations. Neither were the numeric dominant in terms of benthic community structure (see Section 3.C), but as stated previously, they were present in sufficient biomass density to analyze.

The shrimp and scallops were analyzed to be representative of commercially important organisms that use the basin and general disposal site vicinity.

Samples were collected and analyzed using methods similar to the procedures recommended for bioassay/bioaccumulation testing required to obtain an ocean disposal permit for a particular project (EPA/COE, 1977). Some modifications were employed, to increase accuracy, as outlined in Tables 3.B.3 - 19 and 20.

The partitioning of chemicals into biotic tissue in the environment is a highly variable phenomenon. It is inherently dependent on the age,

physiological metabolism, reproductive status and lipid content of the organisms analyzed. The analytical limitations also impart variability to the data. For these reasons, statistical analyses of the biotic residue results at MBDS are minimal, and quantifications are generalized. The large replicate variabilities (in general) forbid strict statistical interpretation, since interstation results would be easily correlated.

#### Metals

Approximately 200 chemical determinations of tissue trace metal content in Nephtys incisa were obtained (see Tables 3.B.3-1 through 5). These are triplicate analyses, where possible. The bivalves Astarte sp. and Platopecten sp. were analyzed by 54 data points (Tables 3.B.3-7 and 8) and shrimp Pandalus borealis by 18 data points. Scheffe test results of ANOVA statistics, however, on log transformed data only indicated cadmium tissue levels at the sand reference site in September were statistically higher than the other stations. This value however was the mean of a duplicate analysis.

#### Arsenic

Reference area (MBDS-REF) arsenic residue in Nephtys incisa ranged from 5.03 ppm to 89.7 ppm dry weight. The MBDS-ON data were lower at 17.7 ppm to 18.9 ppm and MBDS-OFF analysis reported 31.0 ppm. Sandy reference substrate (MBDS-SRF) Nephtys incisa had values in the 21.2 ppm to 58.7 ppm range and MBDS-NES averaged 36.5 ppm. Bivalve arsenic concentrations ranged from 6.16 ppm (scallop) to 23.6 ppm (Astarte sp) and shrimp tissue ranged from 0.15 ppm on dredged material (MBDS-ON) to 0.29 ppm for MBDS-REF.

These ranges indicate no quantitative differences in the arsenic residue levels from organisms on dredged material in comparison to various reference locations. The highest reported value of 89.7 ppm (S.D.=6.7, n=3) dry weight convert to 17.8 ppm (S.D. = 0.3, n=3) wet weight for Nephtys incisa, at MBDS-REF in January 1986. These values are all quantitatively low, with Murray and Norton (1982) reporting invertebrate arsenic levels in the 0.6 to 150 ppm wet weight range, and finfish at <0.2 ppm to 26 ppm. Maria et al. (1986) reported arsenic residues in molluscs ranging from eight to 22 ppm dry weight and in finfish of 0.6 to 6 ppm dry weight. EPA (1985) health assessment documentation for inorganic arsenic lists 50 ug/day as typical dietary intakes.

In summary, arsenic levels in biotic tissues from dredged material disposal areas are not elevated above ambient concentrations at MBDS. The levels recorded for this study are not quantitatively elevated in comparison to other data. Arsenic tissue residues in invertebrates ranged from 3 to 18 ppm wet weight.

## Lead

MBDS-REF lead levels in Nephtys incisa ranged from 3.84 to 4.54 ppm dry weight. On dredged material, lead residues ranged from 3.27 to 6.08 ppm MBDS-OFF ranged from 4.69 to 9.6 ppm while the sand reference organisms ranged 1.01 ppm to 7.56 ppm with MBDS-NES at 7.6 ppm. Analysis of Nephtys incisa from recently deposited material showed on dredged material averaging 6.93 ppm (S.D. = 3.54, n=3) with remote areas ranging from 5.93 to 6.23 ppm dry weight. Bivalves contained lead levels on and off MBDS in the 0.245 ppm to 1.76 ppm range, the lower value from one scallop sample obtained on dredged material. The highest lead value reported was off dredged material (MBDS-OFF) in September 1987, at 9.6 ppm dry weight. The 6.08 ppm dry weight value from MBDS-ON in September 1985 converts to 1.09 ppm wet weight.

Gilbert (1976) reported Nephtys lead concentrations from 19 stations throughout the Gulf of Maine as ranging from 5 to 24 ppm wet weight with stations in the vicinity of MBDS averaging 8.67 ppm (S.D. = 0.58, n=3). The bivalve Arctica islandica was measured by Phillips et al. (1987) to contain 0.103 ppm to 7.86 ppm dry weight from the outer continental shelf. Lead residues ranged from <0.2 ppm wet weight to 1.2 ppm wet weight in invertebrates (shellfish) from coastal England and from <0.1 to 0.2 ppm wet weight for finfish there (Murray and Norton, 1982).

In summary, there were no significant differences among lead residue levels for the reference areas versus the dredged material disposal areas. Generally invertebrate tissue levels were all in the 0.7-1.2 ppm wet weight range.

## Zinc

MBDS-REF zinc tissue residue data ranged from 177 to 202 ppm dry weight with MBDS-ON ranging from 181 to 216 ppm. MBDS-OFF zinc dry weight concentration was 233 ppm, while sand stations in the vicinity had Nephtys incisa zinc residues of 58.8 to 244 ppm dry weight. Bivalves ranged 59.8 to 89.3 ppm in dry weight tissue levels.

Gilbert (1976) identified zinc residues in Nephtys incisa at 19 stations throughout Massachusetts Bay as ranging from 31 to 137 ppm wet weight. In the vicinity of MBDS, wet weight values from Gilbert (1976) were identified as averaging 51 ppm (S.D. = 10.6, n=3). Phillips et al. (1987) identified zinc residues (dry weight) in Arctica islandica as ranging from 71.5 to 172 ppm. Murray and Norton (1982) listed invertebrate zinc wet weight as ranging from 15 to 410 ppm and finfish residue from 2.9 to 6.5 ppm.

In summary, zinc tissue residue levels are not different from organisms off dredged material in comparison to organisms on dredged material. Zinc residue levels are generally from the range of 30 to 40 ppm wet weight or 60 to 240 ppm dry weight for Nephtys incisa. Bivalve concentrations ranged 60 to 90 ppm dry weight.

## Chromium

MBDS-REF chromium levels in Nephtys incisa ranged from 0.54 to 0.69 ppm dry weight (0.12 to 0.18 ppm wet weight). On dredged material chromium residues ranged from 0.8 to 1.4 ppm dry weight (0.16 to 0.25 ppm wet weight). MBDS-OFF had dry weight chromium levels at 0.65 ppm while the MBDS-SRF and MBDS-NES ranged from 0.8 to 0.93 ppm. Bivalve chromium levels at MBDS ranged 0.8 to 2.1 ppm dry weight.

Gilbert (1976) identified Nephtys sp. chromium tissue levels throughout Massachusetts Bay as ranging from 1.1 to 4.8 ppm wet weight and stations in the vicinity of MBDS as having an average of 1.7 ppm (S.D. = 0.2, n=3) value. Phillips et al. identified outer continental shelf bivalve (Arctica islandica) concentrations ranging from 1.22 to 4.45 ppm dry weight.

In summary, the 0.12 to 0.65 ppm wet weight concentrations in Nephtys incisa are characteristic of low chromium concentrations. Dry weight ranges were from 0.64 to 1.39 ppm in Nephtys. Organisms sampled from dredged material do not exhibit any significant elevation over organisms from reference areas. In comparison to earlier work (Gilbert, 1976) the present values are lower than historic ones, which could be a function of analytical advances.

## Copper

MBDS-REF copper residue concentrations in Nephtys incisa ranged from 6.30 ppm to 9.75 ppm dry weight. MBDS-ON had similar levels ranging from 9.66 to 15.7 ppm dry weight. MBDS-OFF ranged from 7.8 to 14.1 ppm while the sandier stations ranged from 7.42 to 10.1 ppm. The September 1987 sampling of Nephtys incisa from recently deposited dredged material had 7.3 ppm (S.D. = 1.31, n=3) concentration, while areas 1 and 4 kilometers remote from MBDS had dry weight values of 11.9 ppm (S.D. = 2.1, n=3) and 13.4 ppm (S.D. = 2.57, n=3) respectively. Bivalve levels ranged from 0.87 ppm to 14.2 ppm dry weight, with the former representing scallop concentrations on dredged material and the latter value is Astarte spp. at MBDS-REF.

Gilbert (1976) identified Nephtys sp. wet weight tissue concentration of copper at 19 stations throughout Massachusetts Bay as ranging from 1.0 to 8.6 ppm, with stations in the vicinity of MBDS having an average of 2.3 ppm (S.D. = 0.66, n=3). Arctica islandica dry weight concentrations from the outer continental shelf (Phillips et al. 1987) ranged from 4.19 to 13.6 ppm. Murray and Norton (1982) described coastal invertebrates from England as having a 1.3 to 254 ppm dry weight copper concentration, with finfish ranging 0.4 to 1.4 ppm.

In summary, MBDS-REF Nephtys incisa tissue residue copper levels of 1.3 to 2.5 ppm wet weight are quantitatively similar to those organisms from MBDS-ON, 2.00-2.76 ppm and other stations in this study. These

values are in good overall agreement with Gilbert's (1976) range for Massachusetts Bay and Phillips (1987) outer continental shelf bivalve concentrations.

#### Cadmium

MBDS-REF cadmium residue in Nephtys incisa tissue ranged from 0.68 ppm to 1.12 ppm dry weight. MBDS-ON tissue residue ranged from 0.97 ppm to 0.713 ppm and MBDS-OFF ranged from 0.67 ppm to 0.776 ppm. Tissue levels from MBDS sand reference site was 2.94 ppm dry weight from duplicate analyses in September 1985 and 4.72 ppm for a single analysis in January 1986. The MBDS-NES site single analysis was 1.44 ppm dry weight in September 1986. On recently deposited dredged materials, cadmium was 0.53 ppm dry weight (S.D. = 0.06, n=3); 1 kilometer southwest, Nephtys incisa residue levels averaged 0.6 ppm (S.D. = 0.2, n=3); and 4 kilometers south of MBDS Nephtys incisa tissue cadmium residues were 0.8 ppm dry weight (S.D. = 0.17, n=3).

Cadmium levels for Astarte sp. ranged from 4.15 ppm to 7.26 ppm dry weight and scallop tissue (single sample) had a 3.45 ppm dry weight level. The 5.42 ppm MBDS-SRF September 1985 was statistically higher than other samples, but this is a statistical artifact of comparing single samples since quantitatively this is not an unreasonable value. Shrimp tissue, Pandalus borealis, had 0.17 ppm (S.D. = 0.02, n=3) to 0.29 ppm (S.D. = 0.05, n=3) September 1985 and January 1986 values while the MBDS-ON samples were lower at 0.15 ppm (S.D. = 0.02, n=3), all wet weight analyses.

Gilbert (1976) identified Nephtys sp. cadmium tissue levels throughout Massachusetts Bay as ranging from 0.31 to 2.71 ppm wet weight, with stations in MBDS vicinity having an average of 0.387 ppm (S.D. = 0.065, n=3). Phillips et al. (1987) reported dry weight bivalve (Arctica islandica) concentration ranging from 0.458 ppm to 6.97 ppm. Invertebrate concentrations in coastal England were reported by Murray and Norton (1982) as <0.2 to 12 ppm wet weight, with shrimp at 0.3 ppm, and finfish cadmium levels ranging from <0.1 to 0.2 ppm. wet weight.

In summary, MBDS-REF Nephtys incisa cadmium tissue range of 0.68 to 1.12 ppm dry weight (0.123 ppm to 0.2 ppm wet weight) is in generally good agreement with the literature. No significant elevations in stations on dredged material or in the vicinity of MBDS have been reported for cadmium in Nephtys incisa, shrimp, or scallop.

#### Mercury

Mercury (along with PCB -2 ppm) has a FDA action limit residue level established for the human consumption of fish at 1.0 ppm wet weight (CFR 22 May 1984-FDA Compliance Policy Guide). MBDS-REF mercury residue in tissue of Nephtys incisa ranged from 0.028 ppm to 0.074 ppm dry weight and from 0.005 ppm to 0.015 ppm wet weight. MBDS-ON dredged material site

ranged from 0.082 to 0.074 ppm dry weight. MBDS-OFF dry weight mercury concentrations had a range of <0.04 to 0.034 ppm dry weight. The Nephtys tissue from the sandy stations had dry weight mercury values ranging from 0.088 to 0.565 ppm (0.011 to 0.079 ppm wet weight). Other Nephtys incisa tissue on recently deposited dredged material and two stations outside MBDS boundary was <0.03 ppm dry weight. These mercury data sets were highly variable due to low sample tissue weight, but all values are quantitatively very low. Bivalve mercury data showed Astarte sp. ranging from 0.380 to 0.609 ppm dry weight, and a scallop sampled from MBDS-ON had 0.222 ppm dry weight value. Shrimp ranged from 0.047 ppm to 0.11 ppm wet weight at MBDS-REF with MBDS-ON residue intermediate at 0.056 ppm (S.D. = 0.002, n=3) wet weight.

Gilbert (1976) identified wet weight mercury levels in Nephtys sp from 19 stations throughout the Massachusetts Bay systems as ranging from <0.01 ppm to 0.130 ppm. In the vicinity of MBDS, Gilbert (1976) recorded mercury residues at <0.020 ppm. Phillips (1987) presents outer continental shelf mercury residue in the bivalve Arctica islandica as ranging from 0.004 ppm to 0.079 ppm dry weight. Invertebrate data from Murray and Norton (1982) presents a mercury residue range of <0.01 to 0.29 ppm wet weight and a finfish tissue range of 0.05 ppm to 0.76 ppm wet weight.

In summary, the 0.005 to 0.015 ppm wet weight range for Nephtys incisa mercury residues at reference areas at MBDS and on dredged material areas are in low concentration relative to the 1984 FDA guidelines for seafood. Similarly, bivalve and shrimp residue levels are also low. No significant differences are evident on or off dredged material.

#### Iron

Iron was analyzed in Nephtys incisa tissue to allow a level of comparison of the potential for excessive gut sediment levels if disparate or anomolous data was obtained. Iron ranged from 175 ppm dry weight to 1341 ppm dry weight for all stations. No significant correlations with residue levels versus iron levels are obvious.

#### Organic Residue Levels

Organic residue levels in and near MBDS were measured in 32 Nephtys incisa samples one scallop (Plactopecten magellanicus) and nine shrimp (Pandalas borealis) samples for PCB at various seasons. DDT was measured in three Nephtys incisa and two Astarte sp. samples from reference areas in June 1985. PAH levels were measured in 24 samples, 15 of which were analyzed for 12 specific compounds in addition to total PAH residue.

Organic residue levels in biotic tissue are particularly variable in accordance with whole body lipid content. The reproductive state of the organisms analyzed can have significant influence on the organic residue levels. The overall low (and below detection) levels reported here are



not classifiable into seasonal components because they are predominantly at or below instrument detection limits.

#### DDT

DDT was measured for MBDS reference area and was found to be below instrument detection limits of 0.028 to 0.079 ppm dry weight (0.005 to 0.012 ppm wet weight) for five Nephtys incisa samples.

#### PCB

The FDA action level for PCB in edible tissues of finfish is currently placed at 2.0 ppm wet weight (CFR 22 May 1984 - FDA Compliance Guidelines).

PCB residue concentrations from Nephtys incisa at MBDS-REF, MBDS-OFF, MBDS-SRF and MBDS-NES were below instrument detection limits for samples obtained during June 1985, September 1985 and January 1986 (instrument detection levels ranged from 0.006 to 0.150 ppm wet weight).

At MBDS-ON, Nephtys incisa PCB tissue residue were below a 0.84 ppm dry weight (0.15 ppm wet weight) detection limit in September 1985. In January 1986, one sample of Nephtys incisa tissue was obtained and it had a PCB residue level of 2,500 ppm dry weight (0.519 ppm wet weight). Subsequent studies were conducted at MBDS and remote to MBDS in September 1987 to analyze PCB tissue residues using substantially lower detection limits. The average MBDS-REF dry weight PCB tissue concentration was 0.2921 ppm (S.D. = 0.1828, n=3). MBDS-OFF dry weight PCB residue averaged 0.06675 ppm (S.D. = 0.3526, n=3). Samples from a recent dredged material disposal area averaged 0.03486 ppm (S.D. = 0.3196, n=3); while an area 1 kilometer southwest of the disposal area averaged 0.7852 ppm (S.D. = 0.7363, n=3) dry weight. Four kilometers southwest of MBDS Nephtys incisa PCB residues averaged 0.1480 ppm (S.D. = 0.00931, n=3) dry weight. All of these values are highly variable (6% to 94% intrastation variability). Caution should be used in interpreting these variable data, but they generally are greater than previous investigations placing PCB concentrations at or below the 0.15 ppm dry weight level, but still they are all quantitatively low and translate to very low wet weights.

Bivalve PCB levels (Astarte sp. from MBDS-REF, MBDS-SRF, and MBDS-NES; and one Plactopecten magellanicus at MBDS-ON) in tissue's at MBDS were all below instrument detection levels in the 0.08 to 0.28 ppm wet weight levels. Shrimp, Pandalus borealis, level in September 1985 MBDS-REF was 0.09 ppm (S.D. = 0.01, n=3) wet weight, while MBDS-ON was 0.17 ppm (S.D. = 0.07, n=3). In January 1986, MBDS-REF shrimp tissue PCB residue was 0.08 ppm (S.D. = 0.02, n=3) wet weight.

Studies sponsored by the Corps of Engineers have found Nephtys incisa PCB tissue levels in Long Island Sound to vary from 0.2-0.3 ppm dry weight at "reference" areas to 1.2 ppm dry weight for areas impacted by dredged

material disposal. PCB concentrations from areas in the Gulf of Maine around the Cape Arundel Disposal Site were generally below the 0.2-0.4 ppm detection limit.

Swart (1987) examined PCB concentration in various species from Massachusetts Bay. He reported wet weight concentrations of winter flounder, Pseudopleuronectes americanus, ranging from 0.05 ppm to 0.17 ppm; lobster, Homarus americanus, ranging from 0.24 ppm to 0.88 ppm; surf clam, Spisula solidissima from 0.0 to 0.02 ppm; black clam, Arctica islandica, from 0.0 to 0.5 ppm blue mussel; Mytilus edulis, from 0.0 to 0.48 ppm; and hard clam, Mercenaria mercenaria at 0.13 ppm. Boehm (1984) studying organic contaminants throughout Massachusetts Bay lists PCB wet weight levels for jonah crab, Cancer borealis, as ranging from 0.065 ppm to 0.279 ppm; winter flounder, Pseudopleuronectes americanus, as ranging from 0.090 ppm to 0.135 ppm and dab, Hippoglossoides platessoides, ranging from 0.010 ppm to 0.034 ppm. Shrimp from European (North Sea) waters were reported as having PCB residues in the 0.048 ppm to 0.180 ppm range, while polychaete (Arenicola marina) wet weight concentrations of PCB ranged from 0.05 ppm to 0.091 ppm at a reference station (Goerke et al., 1979). Invertebrates around coastal England had PCB residues ranging from <0.01 to 0.16 ppm and finfish ranging from 0.01 ppm to 0.15 ppm wet weights (Murray and Norton, 1982).

In summary, the levels of PCB residues recorded at MBDS were generally very low, all less than 0.52 ppm wet weight.

The presence of PCB, a xenobiotic in biotic tissues indicates contamination of the ecological system. The most recent sampling efforts at MBDS using lowered PCB detection limits indicates all locations in Stellwagen Basin are impacted by PCB, but the uniform spatial distribution in the 0.009 ppm (4 kilometers southwest of MBDS, a reference site) to 0.8 ppm (1 kilometer southwest of Disposal Buoy, an old disposal point) dry weight concentrations, does indicate elevated PCB contamination on dredged material. The values are low, and represent background contamination, as indicated by other sampling throughout Massachusetts Bay, plus a potential elevation attributable to dredged material disposal on the disposal mound. The reference dry weight value of 0.2921 ppm (S.D. = 0.1828, n=3) may be representative of basin wide conditions (for fine silt substrate), while samples from within MBDS (MBDS-OFF) averaging 0.6675 ppm (S.D. 0.3526, n=3) and in older deposits southwest of MBDS averaging 0.7852 ppm (S.D. = 0.6802, n=3) dry weights, may represent disposal influence.

#### PAH

In September 1985 and January 1986, a total of nine Polycyclic Aromatic Hydrocarbon samples were obtained at MBDS. These values were reported as total PAH levels in shrimp (Pandalus borealis) tissue. MBDS-REF PAH residue averaged 0.09 ppm (S.D. = 0.02, n=3) wet weight in September 1985 and 1.4 ppm (S.D. = 0.7, n=3) wet weight in January 1986. PAH tissue residue levels in shrimp at MBDS-ON averaged <0.10 ppm wet weight.

Additional PAH residue analyses in Nephtys incisa were performed in September 1987, analyzing for specific compounds as recommended in Clarke and Gibson (1987). These results showed MBDS-REF PAH totals averaging 0.3564 ppm (S.D. = 0.130, n=3) dry weight.

An area four kilometers south of MBDS averaged 0.1746 ppm (S.D. = 0.047, n=3) for PAH residue. MBDS-OFF, that area within MBDS unimpacted by dredged material disposal, had highly variable results averaging 0.7741 ppm (S.D. = 0.9144, n=3) dry weight. Analysis of Nephtys incisa on the dredged material disposal area revealed a significant increase in total PAH; averaging 2.4767 ppm (S.D. = 0.2949, n=3). An area 1 kilometer southwest of the disposal buoy, but on dredged material disposed in prior years averaged 2.1962 ppm (S.D. = 0.7794, n=3) dry weight. The lowest concentration area (0.1746 ppm) 4 km south of MBDS was dominated by phenanthrene (36.8%); pyrene (28.9%) and fluoranthene (25.6%). The MBDS-REF area (0.3564 ppm) was dominated by benzo (a) anthracene and chrysene (33.2%), pyrene (16.3%), benzo(a) pyrene (15.1%) and fluoranthene (14.6%). MBDS-OFF (0.7741 ppm) was dominated by benzo(a) anthracenes and chrysene pyrene (20.4%) and fluoranthene (18.0%). At the dredged material disposal site (2.4767 ppm) the dominant PAH compounds in Nephtys incisa tissue were benzo(a) anthracene and chrysene (44.0%); fluoranthene (16.5%) and pyrene (14.7%). One kilometer southwest of the disposal buoy (2.1962 ppm) the total PAH levels in Nephtys incisa was dominated by benzo(a) anthracene and chrysene (54.3%); benzo(a) pyrene (18.0%) and pyrene (14.9%).

Boehm (1984) reported dry weight total PAH tissue residue for PAH in Jonah crabs from Boston Harbor/Mass/Cape Cod Bay as ranging from 0.007 ppm to 0.457, dab from <0.001 ppm to 0.012 ppm and flounder from <0.001 ppm to 0.010 ppm.

Although little comparative literature is available regarding Nephtys incisa PAH tissue levels, this study showed elevated PAH tissue levels at areas impacted by dredged material. The dominant specific compound group was benzo(a) anthracene and chrysene. Stations sampled that were impacted by dredged material had a total PAH range from 2.2 ppm to 2.5 ppm dry weight.

Areas not significantly impacted by dredged material had total PAH ranges from 0.17 ppm to 0.77 ppm dry weight and were not heavily dominated by any one compound, but generally impacted by phenanthrene, fluoranthene, pyrene, and benzo(a) anthracene and chrysene.

#### Summary - Tissue Residues

The examination of available polychaete, bivalve and crustacean tissue at MBDS exhibit low levels of metal residues and no statistical elevations over ambient (reference) residues. Organic residue levels data were generally highly variable and quantitatively low. One sample of Nephtys incisa tissue from January, 1986, on dredged material, exhibited an elevated PCB concentration of 0.52 ppm wet weight, however previous and

subsequent sampling did not reveal similar contamination. PAH contamination was statistically elevated on areas of dredged material, in comparison to reference sites. Quantatively, PAH levels were less than 2.5 ppm dry weight and predominantly influenced by benzo (a) anthracene and chrysene.

Table 3.B.3-1  
Trace Metal Concentrations in *Nephtys incisa*  
From MBDS reference Station (MBDS-REF)  
Concentrations as ppm

|          |    | <u>June 1985</u>         | <u>September 1985</u> | <u>January 1986</u> | <u>September 1987</u> |
|----------|----|--------------------------|-----------------------|---------------------|-----------------------|
| Arsenic  | -D | 50.3 (2.44) <sup>1</sup> | 67.0 (22.7)           | 89.7 (6.7)          | NA                    |
|          | -W | 9.15 (1.27)              | 12.1 (4.0)            | 17.8 (0.3)          |                       |
| Lead     | -D | 3.84 (0.84)              | 4.27 (0.83)           | 4.54 (0.15)         | 4.6 (0.86)            |
|          | -W | 0.70 (0.21)              | 0.77 (0.16)           | 0.90 (0.03)         |                       |
| Zinc     | -D | 202 (14)                 | 223 (52)              | 177 (3)             | NA                    |
|          | -W | 36.7 (5.5)               | 41 (9)                | 35 (1)              |                       |
| Chromium | -D | 0.66 (0.12)              | 0.99 (0.07)           | 0.639 (0.104)       | NA                    |
|          | -W | 0.12 (0.03)              | 0.18 (0.01)           | 0.127 (0.021)       |                       |
| Copper   | -D | 8.22 (1.81)              | 9.37 (2.21)           | 6.30 (0.24)         | 9.75 (1.25)           |
|          | -W | 2.49 (0.36)              | 1.70 (0.40)           | 1.25 (0.05)         |                       |
| Cadmium  | -D | 1.12 (0.38)              | 0.680 (0.162)         | 0.72 (0.155)        | 0.7 (0.1)             |
|          | -W | 0.20 (0.60)              | 0.123 (0.028)         | 0.144 (0.031)       |                       |
| Mercury  | -D | 0.028 <sup>2</sup>       | 0.072 (0.010)         | 0.074 (0.04)        | <0.03                 |
|          | -W | 0.005                    | 0.013 (0.002)         | 0.015 (0.001)       |                       |
| Iron     | -D | N.A.                     | 963 (38)              | 945 (21)            | 1158.3 (573.1)        |
|          | -W |                          | 175 (9)               | 188 (4)             |                       |

1 - Mean (Standard Deviation) of 3 Analyses.

2 - Single Analysis

N.A. - Not Analyzed.

D - Dry Weight

W - Wet Weight

Table 3.B.3-2 Trace Metal Concentrations in Nephtys incisa  
from MBDS on Dredged Material  
Concentrations as ppm

|             | MBDS-ON<br>September 1985 | MBDS-ON<br>January 1986 |
|-------------|---------------------------|-------------------------|
| Arsenic -D  | 19.7 <sup>1</sup>         | 18.9 <sup>1</sup>       |
| -W          | 3.53                      | 3.92                    |
| Lead -D     | 6.08                      | 3.27                    |
| -W          | 1.09                      | 0.68                    |
| Zinc -D     | 216                       | 181                     |
| -W          | 38                        | 38                      |
| Chromium -D | 1.39                      | 0.776                   |
| -W          | 0.248                     | 0.161                   |
| Copper -D   | 15.7                      | 9.66                    |
| -W          | 2.76                      | 2.00                    |
| Cadmium -D  | 0.97                      | 0.713                   |
| -W          | 0.173                     | 0.148                   |
| Mercury -D  | 0.082                     | 0.074                   |
| -W          | 0.015                     | 0.015                   |
| Iron -D     | 833                       | 696                     |
| -W          | 148                       | 144                     |

1. mean of duplicate analysis
2. mean (std. dev.) of 3 Analyses

Table 3.B.3-3 Trace Metal Concentrations in  
Nephtys incisa From MBDS

Concentrations As ppm

|             | MBDS-OFF<br>September 1985 | MBDS-OFF<br>September 1987 |
|-------------|----------------------------|----------------------------|
| Arsenic -D  | 31.0 <sup>1</sup>          | NA                         |
| -W          | 5.3                        |                            |
| Lead -D     | 4.69                       | 9.6 (2.7) <sup>3</sup>     |
| -W          | 0.80                       |                            |
| Zinc -D     | 233                        | NA                         |
| -W          | 40                         |                            |
| Chromium -D | 0.652                      | NA                         |
| -W          | 0.112                      |                            |
| Copper -D   | 7.18                       | 14.1 (1.9)                 |
| -W          | 1.22                       |                            |
| Cadmium -D  | 0.776                      | 0.67 (0.06)                |
| -W          | 0.132                      |                            |
| Mercury -D  | 0.034                      | <0.04                      |
| -W          | 0.006                      |                            |
| Iron -D     | 749                        | 1341 (687.4)               |
| -W          | 128                        |                            |

1 - Mean of Duplicate Analysis

2 - Single Analysis

3 - Mean (standard deviation) of 3 analyses

Table 3.B.3-4 Trace Metal Concentrations in  
Nephtys incisa from MBDS.  
 Concentrations As ppm

|             | MBDS-SRF<br>September 1985<br>Sand Ref | MBDS-NES<br>September 1985 | MBDS-SRF<br>January 1986 |
|-------------|--|----------------------------|--------------------------|
| Arsenic -D  | 58.7 <sup>1</sup>                      | 36.5 <sup>2</sup>          | 21.2                     |
| -W          | 8.77                                   | 4.39                       | 2.94                     |
| Lead -D     | 7.56                                   | 7.60                       | 1.01                     |
| -W          | 1.12                                   | 0.92                       | 0.141                    |
| Zinc -D     | 244                                    | 239                        | 58.8                     |
| -W          | 36                                     | 29                         | 8.21                     |
| Chromium -D | 0.827                                  | 0.797                      | 0.93                     |
| -W          | 0.123                                  | 0.096                      | 0.13                     |
| Copper -D   | 10.1                                   | 8.68                       | 7.42                     |
| -W          | 1.39                                   | 1.05                       | 1.04                     |
| Cadmium -D  | 2.94                                   | 1.44                       | 4.72                     |
| -W          | 0.435                                  | 0.173                      | 0.66                     |
| Mercury -D  | 0.467                                  | 0.088                      | 0.565                    |
| -W          | 0.069                                  | 0.011                      | 0.079                    |
| Iron -D     | 665                                    | 539                        | 344                      |
| -W          | 99                                     | 65                         | 48                       |

1 - mean of duplicate analysis

2 - single analysis

3. mean standard deviation of analyses

Table 3.B.3-5 Trace Metal Concentrations in Nephtys incisia within and Remote from MBDS. September 1987

|            | On Dredged<br>Material | 1km<br>Southwest<br>(Old Dredged Material) | 4km<br>South   |
|------------|------------------------|--|----------------|
| Arsenic -D | 6.93 (3.54             | 5.93 (3.59)                                | 6.23 (1.64)    |
| Copper -D  | 7.3 (1.31)             | 11.9 (2.1)                                 | 13.4 (2.57)    |
| Cadmium -D | 0.53 (0.06)            | 0.6 (0.2)                                  | 0.8 (0.17)     |
| Mercury -D | <0.02                  | <0.03                                      | <0.03          |
| Iron -D    | 796.3 (107.6)          | 1175 (212.8)                               | 1231.3 (295.8) |

mean (std. dev.) of three replicate analyses

Note: See also MBDS-REF and MBDS-OFF data for September 1987 in Tables 3.B.3-1 and 3.B.3-3.

Table 3.B.3-6 Trace Metal Concentrations in MBDS Benthic Organisms From MBDS-REF, June 1985

Concentrations as ppm

|             | <u>Astarte Spp.</u> |       |
|-------------|---------------------|-------|
|             | Small               | Large |
| Arsenic -D  | 23.6                | 17.8  |
| Lead -D     | 1.76                | 1.48  |
| Zinc -D     | 65.2                | 89.3  |
| Chromium -D | 1.45                | 0.79  |
| Copper -D   | 12.3                | 14.2  |
| Cadmium -D  | 7.26                | 5.13  |
| Mercury -D  | 0.380               | N.A.  |

N.A. - Not Analyzed Due To Insufficient Tissue Mass.



Table 3.B.3.7 Trace Metal Concentrations in Bivalve Tissue  
(Astarte spp. and Plactopecten megellanicus)  
 Collected at MBDS

Concentrations as ppm

|             | <u>Astarte spp.</u>        |                            | <u>Plactopecten</u>      |                           |
|-------------|----------------------------|----------------------------|--------------------------|---------------------------|
|             | MBDS-SRF<br>September 1985 | MBDS-NES<br>September 1985 | MBDS-SRF<br>January 1986 | MBDS-ON<br>September 1985 |
| Arsenic -D  | 13.0 <sup>1</sup>          | 9.57 (2.67) <sup>2</sup>   | 21.2 <sup>1</sup>        | 6.16 <sup>1</sup>         |
| Lead -D     | .583                       | .786 (.136)                | 1.01                     | .245                      |
| Zinc -D     | 69.7                       | 67.0 (8.46)                | 58.8                     | 88.9                      |
| Chromium -D | 1.98                       | 2.09 (0.26)                | 0.929                    | .278                      |
| Copper -D   | 11.9                       | 13.4 (1.97)                | 7.42                     | .867                      |
| Cadmium -D  | 5.42                       | 4.15 (0.42)                | 4.72                     | 3.45                      |
| Mercury -D  | .609                       | .481                       | 0.565                    | .222                      |
| Iron -D     | 696                        | 506 (90)                   | 344                      | 22.4                      |

1. Single analysis

2. mean (std. dev.) of three replicate analyses

Table 3.B.3-8 Trace Metal Concentrations In Shrimp  
Pandalus borealis, From MBDS

Concentrations as ppm Wet Weight

|         | MBDS-REF<br><u>September 1985</u> | MBDS-ON<br><u>September 1985</u> | MBDS-REF<br><u>January 1986</u> |
|---------|-----------------------------------|----------------------------------|---------------------------------|
| Cadmium | 0.17 (0.02)                       | 0.15 (0.02)                      | 0.29 (0.05)                     |
| Mercury | 0.047 (0.002)                     | 0.056 (0.002)                    | 0.11 (0.01)                     |

Table 3.B.3-9 Trace Organic Concentrations in  
Nephtys incisa from MBDS

Concentrations in ppm

MBDS-REF

|                 | June 1985                  | September 1985             | January 1986               | September 1987  |
|-----------------|----------------------------|----------------------------|----------------------------|---|
| PCB-D           | <0.146<br><0.157<br><0.136 | <0.440<br><0.200<br><0.250 | <0.360<br><0.490<br><0.500 | 0.1123<br>0.2862<br>0.4748<br>(avg. =<br>0.2921 S.D.<br>= 0.1828) |
| -W              | <0.026<br><0.026<br><0.027 | <0.080<br><0.036<br><0.046 | <0.072<br><0.097<br><0.099 |   |
| DDT-D           | <0.028<br><0.030<br><0.030 |                            |                            |   |
| -W              | <0.005<br><0.005<br><0.006 |                            |                            |   |
| -D = Dry Weight |                            |                            |                            |   |
| -W = Wet Weight |                            |                            |                            |   |

Table 3.B.3-10 Trace Organic Concentrations in  
Nephtys incisa from MBDS

Concentrations in ppm

MBDS-ON

|                 | September 1985   | January 1986 |
|-----------------|------------------|--------------|
| PCB-D           | <0.700<br><0.840 | 2.500        |
| -W              | <0.121<br><0.150 | 0.519        |
| -D = Dry Weight |                  |              |
| -W = Wet Weight |                  |              |

Table 3.B.3-11 Trace Organic Concentrations in  
Nephtys incisa from MBDS

Concentrations in ppm  
MBDS-OFF

|       | September 1985   | September 1987  |
|-------|------------------|---|
| PCB-D | <0.430<br><0.500 | 0.3571<br>0.5945<br>1.0509<br>(avg = 0.6675<br>S.D.=0.3526) |
| -W    | <0.075<br><0.083 |   |

Table 3.B.3-12 Trace Organic Concentrations in  
Nephtys incisa from MBDS

Concentrations in ppm

|       | MBDS-SRF<br>September 1985 | MBDS-NES<br>September 1985 |
|-------|----------------------------|----------------------------|
| PCB-D | <0.250<br><0.240           | <0.330                     |
| -W    | <0.036<br><0.036           | 0.040                      |

Table 3.B.3-13 Trace Organic Concentrations in  
Nephtys incisa from MBDS

Concentrations in ppm

September 1987

|       | On Dredged<br>Material | 1 kilometer<br>Southwest of<br>Disposal Buoy<br>(On Old Dredged Material) | 4 kilometers<br>Southwest of<br>Disposal Buoy |
|-------|------------------------|---|---|
| PCB-D | 0.6895                 | 1.5683  | 0.1582  |
|       | 0.3004                 | 0.1070  | 0.1457  |
|       | 0.0558                 | 0.6802  | 0.1400  |
|       | avg = 0.3486           | 0.7852  | 0.1480  |
|       | S.D. = 0.3196          | 0.7363  | 0.00931                                       |

Table 3.B.3-14 Trace Organic Concentrations in  
Astarte spp From MBDS

Concentrations are in ppm

|            | MBDS-REF<br>June 1985 | MBDS-SRF<br>September 1985 | MBDS-NES<br>September 1985 | MBDS-SRF<br>January 1985 |
|------------|-----------------------|----------------------------|----------------------------|--------------------------|
| PCB        |                       |                            |                            |                          |
| Dry Weight | <0.414                | <2.400<br><1.000<br><1.900 | <1.700<br><1.900<br><2.200 | <0.570                   |
| Wet Weight | <0.063                | <0.270<br><0.150<br><0.210 | <0.260<br><0.280<br><0.270 | <0.080                   |
| DDT        |                       |                            |                            |                          |
| Dry Weight | <0.079                | NA                         | NA                         | NA                       |
| Wet Weight | <0.012                | NA                         | NA                         | NA                       |

Table 3.B.3-15 PCB Concentrations in the Bivalve  
Plactopecten megellanicus Collected at MBDS  
 September 1985

Concentrations As ppm Dry Weight  
 MBDS-ON  
 PCB Concentrations

Plactopecten megellanicus

<0.210

Table 3.B.3-16 Trace Organic Concentrations In Shrimp  
Pandalus borealis, From MBDS.

Concentrations As ppm Wet Weight

|               | MBDS-REF<br>September 1985 | MBDS-ON<br>September 1985 | MBDS-REF<br>January 1986 |
|---------------|----------------------------|---------------------------|--------------------------|
| Total<br>PCBs | 0.09 $\pm$ 0.01            | 0.17 $\pm$ 0.07           | 0.08 $\pm$ 0.02          |

Table 3.B3-17 Polycyclic Aromatic Hydrocarbons Concentrations  
In Nephthys Incisa at MBIX  
Note: Concentrations as ppb - Parts Per Billion

| Sample ID               | Replicate | Weight<br>Wet | Weight<br>Dry | FL     | PH     | A      | F      | P       | B(a)A+CH | B(b)F  | B(k)F  | B(a)P  | TP     | R(ghi)PE | D(ah)A |
|-------------------------|-----------|---------------|---------------|--------|--------|--------|--------|---------|----------|--------|--------|--------|--------|----------|--------|
| MBDS-OFF<br>avg (S.D.)  | 1         | 1.7692        | 0.3271        | 17.5   | 30.0   | 91.3   | 139.6  | 158.3   | 764.9    | 35.0   | ND(<4) | 173.6  | ND(<4) | 48.8     | ND(<4) |
|                         | 2         | 1.9854        | 0.3671        | ND(<2) | ND(<2) |        |        |         | 207.7    | ND(<4) | ND(<4) | ND(<4) | ND(<4) | ND(<4)   | ND(<4) |
|                         | 3         | 2.5780        | 0.4767        | ND(<2) | (12.3) | ND(<2) | 158.9  | (143.1) | ND(<4)   | ND(<4) | ND(<4) | ND(<4) | ND(<4) | ND(<4)   | ND(<4) |
| MBDS-REF<br>avg. (S.D.) | 1         | 2.6944        | 0.6329        | 11.0   | 37.5   | 22.4   | 51.9   | 58.1    | 118.4    | 9.9    | ND(<4) | 53.8   | ND(<4) | ND(<4)   | ND(<4) |
|                         | 2         | 1.8637        | 0.4378        |        |        |        |        |         |          | ND(<3) | ND(<3) | ND(<3) | ND(<3) | ND(<3)   | ND(<3) |
|                         | 3         | 2.7596        | 0.6482        | (4.6)  | (9.1)  | (8.3)  | (19.0) | 21.1    | (67.9)   | ND(<3) | ND(<3) | (14.1) | ND(<3) | ND(<3)   | ND(<3) |

NOTES: Values reported have been corrected on a replicate basis against internal standard recoveries  
(FL, PH, A, F, P used d<sub>10</sub>PM (X±SD, PSD) = 177.5% ± 36.1%, 20.3%, B(a)A+CH, B(b)F, B(a)P, B(ghi)PE, D(ah)A  
used d12 B(a)A (X±SD, PSD) = 71.8% ± 116.0%, 22.2%). Spike levels were 1000 - 4000g for d10 and 4000g for d12 B(a)A  
per replicate.  
FL = fluorene, PM = phenanthrene, A = anthracene, F = fluoranthene, P = pyrene, B(a)A = benzo(a)pyrene,  
CH = chrysene, B(b)F = benzo(b)fluoranthene, B(k)F = benzo(k)fluoranthene, B(a)P = benzo(a)pyrene,  
IP = indeno(1,2,3-cd)pyrene, B(ghi)PE = benzo(ghi)perylene, D(ah)A = dibenzo(ah)anthracene.

Table 3.B3-18 Polycyclic Aromatic Hydrocarbons Concentrations  
in Nephthys Incisae at MBDS

Note: Concentrations as ppb - Parts Per Billion

| Sample ID                                      | Replicate | Wet    | Dry    | FL     | PH     | A      | F      | P       | B(a)A+CH | B(b)F  | B(k)F  | B(a)P   | TP     | R(ghi)PE | D(ah)A |
|--|-----------|--------|--------|--------|--------|--------|--------|---------|----------|--------|--------|---------|--------|----------|--------|
| 1 kilometer S.W.<br>of Buoy avg<br>(S.D.)      | 1         | 1.8789 | 0.3871 | 8.2    | 42.6   | 33.7   | 135.7  | 327.0   | 1192.7   | 41.7   | ND(<3) | 394.5   | ND(<3) | ND(<3)   | ND(<3) |
|  | 2         | 1.7989 | 0.3706 | ND(<1) |        |        |        |         | 207.7    |        | ND(<3) |         | ND(<3) | 77.0     | ND(<3) |
|  | 3         | 2.2547 | 0.4645 | ND(<1) | (15.8) | (17.8) | (72.3) | (121.7) | (468.8)  | (19.4) | ND(<3) | (105.1) | ND(<3) | ND(<3)   | ND(<3) |
| On dredged material<br>avg. (S.D.)             | 1         | 1.7287 | 0.4910 | 25.0   | 61.4   |        |        |         |          | 35.7   | ND(<4) |         | 65.7   |          | ND(<4) |
|  | 2         | 1.5896 | 0.4514 |        |        | 114.6  | 408.3  | 365.2   | 1089.6   |        | ND(<4) | 261.9   | ND(<4) | 93.4     | ND(<4) |
|  | 3         | 1.6377 | 0.4651 | (2.0)  | (3.0)  | (15.8) | (58.4) | (33.4)  | (137.6)  | (16.5) | ND(<4) | (68.6)  | 64.8   | (21.1)   | ND(<4) |
| 4 kilometers south<br>of MBDS<br>(Avg. (S.D.)) | 1         | 1.2594 | 0.2947 |        |        |        |        |         |          | ND(<6) | ND(<6) | ND(<6)  | ND(<6) | ND(<6)   | ND(<6) |
|  | 2         | 1.7742 | 0.4152 | 10.9   | 64.2   | 4.2    | 4.48   | 50.5    | ND(<6)   | ND(<6) | ND(<6) | ND(<6)  | ND(<6) | ND(<6)   | ND(<6) |
|  | 3         | 1.7308 | 0.3050 | (0.5)  | (11.6) | (0.7)  | (17.0) | (21.6)  | ND(<4)   | ND(<4) | ND(<4) | ND(<4)  | ND(<4) | ND(<4)   | ND(<4) |

NOTES: Values reported have been corrected on a replicate basis against internal standard recoveries  
(FL, PH, A, F, P used d10 PM (X±SD, RSD) = 177.5%, 20.3%, B(a)A+CH, B(b)F, B(a)P, B(ghi)PE, D(ah)A  
used d12 B(a)A (X±SD, RSD) = 71.8% +116.0%, 22.2%). Spike levels were 1000 - 4000g for d10 and 4000g for d12 B(a)A  
per replicate.  
FL = fluorene, PH = phenanthrene, A = anthracene, F = fluoranthene, P = pyrene, B(a)A = benzo(a)pyrene,  
CH = chrysene, B(b)F = benzo(b)fluoranthene, B(k)F = benzo(k)fluoranthene, B(a)P = benzo(a)pyrene,  
IP = indeno(1,2,3-cd)pyrene, B(ghi)PE = benzo(ghi)perylene, D(ah)A = dibenzo(ah)anthracene.

Table 3.B.3-19  
Instrument Operating Conditions and Detection Limits For Metals Analyzed  
By Flame Atomic Absorption Spectrometry

| <u>Element</u> | <u>Wavelength<br/>(nm)</u> | <u>Lamp<br/>Current<br/>(mA)</u> | <u>Silt<br/>Width<br/>(mm)</u> | <u>Gas<br/>Oxidant/<br/>Fuel</u>  | <u>Flame<br/>Type</u> | <u>Minimum<br/>Detection<br/>Limit (ppm)</u> | <u>Sensitivity<br/>pps/0.0044<br/>Abs)</u> | <u>Additional<br/>Comments</u> |
|----------------|----------------------------|----------------------------------|--------------------------------|-----------------------------------|-----------------------|--|--|--------------------------------|
| Cd             | 228.8                      | 4                                | 1.0                            | Air/C <sub>2</sub> H <sub>2</sub> | Oxidizing             | .02  | .04  | D <sub>2</sub> correction      |
| Cu             | 324.7                      | 10                               | 1.0                            | Air/C <sub>2</sub> H <sub>2</sub> | Oxidizing             | 0.04   | 0.1  | D <sub>2</sub> correction      |
| Zn             | 213.9                      | 15                               | 1.0                            | Air/C <sub>2</sub> H <sub>2</sub> | Oxidizing             | 0.015  | 0.002                                      | D <sub>2</sub> correction      |



Table 3.B.3.-20a Instrument Operating Conditions and Detection Limits For Metals  
Analyzed By Graphite Furnace Atomic Absorption Spectrophotometry

| <u>Element</u> | <u>Wave<br/>Length<br/>(nm)</u> | <u>Lamp<br/>Current<br/>(mA)</u> | <u>Slit<br/>Opening<br/>(mm)</u> | <u>Injection<br/>Volume<br/>(<math>\mu</math>l)</u> | <u>Gas</u>                     | <u>Furnace<br/>Conditions</u>  |
|----------------|---------------------------------|----------------------------------|----------------------------------|---|--------------------------------|--|
| As             | 193.7                           | 18                               | 1.0                              | 20  | Ar (3 sec, normal<br>flow, 20) | Dry: 110°C, 30 sec<br>Char: 1200°C, 30 sec<br>Atomize: 2700°C, 8 sec |
| Cd             | 228.8                           | 4                                | 1.0                              | 10  | Ar (3 sec, normal<br>flow, 20) | Dry: 110°C, 22 Sec<br>Char: 350°, 22 Sec<br>Atomize: 2100°C, 7 sec   |
| Cr             | 357.9                           | 14                               | 1.0                              | 20  | Ar (3 sec, normal<br>flow, 30) | Dry: 110°C, 22 Sec<br>Char: 1100°, 22 Sec<br>Atomize: 2700°C, 7 sec  |
| Hg             | 254                             | -                                | -                                | -   | -                              | -  |
| Pb             | 223.3                           | 10                               | 1.0                              | 20  | Ar (3 sec, normal<br>flow, 20) | Dry: 110°C, 22 Sec<br>Char: 750°, 22 Sec<br>Atomize: 2300°C, 7 sec   |

Table 3.B.3-20a  
Continued

| <u>Element</u> | <u>Minimum<br/>Detection<br/>Limit (ppb)</u> | <u>Absolute<br/>Detection<br/>Limit<br/>(picograms)</u> | <u>Sensitivity<br/>(ppb/<br/>0.0044 ABS)</u> | <u>Sensitivity<br/>(picograms/<br/>0.0044 ABS)</u> | <u>Additional<br/>Comments</u> |
|----------------|--|---|--|--|--------------------------------|
| As             | 2  | 40  | 5  | 100  | D <sub>2</sub> correction      |
| Cd             | 0.1  | 1   | 0.3  | 3  | D <sub>2</sub> correction      |
| Cr             | 0.5  | 10  | 0.7  | 14   | D <sub>2</sub> correction      |
| Hg             | 0.5 <sup>a</sup>                             | 500   | --   | --   | Cold vapor analysis            |
| Pb             | 0.5  | 10  | 1  | 20   | D <sub>2</sub> correction      |

Table 3.B.3.-20b Trace Metal Concentrations in Tissues, Precision and Accuracy  
Data (Concentrations as ppm Dry Weight)

| Sample #              | Description  | As     | Cd     | Cr     | Cu     | Pb     | Zn     | Hg<br>ppb |
|-----------------------|--|--------|--------|--------|--------|--------|--------|-----------|
| 2749A                 | <u>Nepthys</u> (CADS) Jar #2<br>sp (Polychaete Worm) | 58.9   | 1.04   | 0.693  | 8.32   | 5.09   | 172    | 70.2      |
| 2749B                 | <u>Nepthys</u> (CADS) Jar #2<br>sp (Polychaete Worm) | 57.4   | 1.01   | 0.612  | 6.97   | 4.05   | 169    | 38.4      |
| 2749C                 | <u>Nepthys</u> CADS) Jar #2<br>sp (Polychaete Worm)  | 51.8   | 1.12   | 0.694  | 7.81   | 3.54   | 176    | <4.94     |
| x                     | 56.0   | 1.05   | 0.666  | 7.70   | 4.23   | 172    | --     | --        |
| +                     | (% Relative Standard Deviation)                      | 6.7    | 5.38   | 7.06   | 8.85   | 18.7   | 2.04   | --        |
| NBS-1566A             | OYSTER TISSUE  | 10.4   | 4.25   | 0.381  | 57.8   | 0.575  | 942    | 39.1      |
| NBS-1566B             | OYSTER TISSUE  | 11.8   | 4.00   | 0.484  | 57.4   | 0.549  | 931    | 40.9      |
| NBS-1566C             | OYSTER TISSUE  | 11.5   | 4.27   | 0.401  | 64.3   | 0.599  | 950    | 43.0      |
| NBS-1566C             | OYSTER TISSUE  | 10.5   | 3.72   | 0.424  | 53.6   | 0.670  | 915    | 41.2      |
| X                     |  | 11.0   | 4.06   | 0.422  | 58.3   | 0.598  | 934    | 41.1      |
| +                     | (% Relative Standard Deviation)                      | + 6.38 | + 6.35 | + 10.6 | + 7.62 | + 8.69 | + 1.62 | + 3.89    |
| Value Reported by NBS |  | 13.4   | 3.5    | 0.64   | 63.0   | 0.48   | 852    | 57.0      |
| +                     | (% Relative Standard Deviation)                      | + 14.2 | + 11.4 | + 42.2 | + 5.55 | + 8.33 | + 1.64 | + 26.3    |

Table 3.B.3.-21 Mercury Replicate Studies  
(ppm Dry Weight)

January 1986

Nephtys incisa

| <u>MBDS</u>     | <u>Mud Reference</u>  |
|-----------------|-----------------------|
| Replicate 1     | 0.079                 |
| Replicate 2     | 0.072                 |
| Replicate 3     | 0.072                 |
| X + S.D. (%RSD) | 0.074 + .004 (5.4%)   |
| <u>MBDS</u>     | <u>Sand Reference</u> |
| Replicate 1     | 0.051                 |
| Replicate 2     | 0.081                 |
| Replicate 3     | 0.045                 |
| X + S.D. (%RSD) | 0.059 + 0.019 (32%)   |

Arctica islandica

| <u>CADS</u>     | <u>Reference</u>   |
|-----------------|--------------------|
| Replicate 1     | 0.129              |
| Replicate 2     | 0.132              |
| Replicate 3     | 0.111              |
| X + S.D. (%RSD) | 0.124 + 0.011 (9%) |

3.C. BIOLOGICAL CHARACTERISTICS

3.C.1 PLANKTON RESOURCES

3C.1.a Phytoplankton

Community Composition and Seasonal Abundance

The species composition and annual cycles of the phytoplankton community in Massachusetts Bay have been described by TRIGOM (1974). The following discussion is based on that work, other studies of Massachusetts Bay (MWRA 1987), and general reports concerning the phytoplankton of northeastern United States coastal waters (Marshall and Cohn 1983, 1984). Included in the TRIGOM report are data from a 1972-1973 study in which five nearshore Massachusetts Bay stations within approximately 4-12 nautical miles of MBDS were sampled on a monthly or bimonthly basis. Limited data is also available from MBDS during the late summer - early fall of 1973 (Martin and Yentsch, 1973).

Phytoplankton communities in the northeastern coastal shield (including Massachusetts Bay) consist of a diverse assemblage of species, the most abundant of which can be divided into three main groups (Marshall and Cohn 1983, 1984). These groups are the small-sized diatoms, the phytoflagellates, and the ultraplankton (2-5 mm in size). The small diatoms (e.g. Skeletonema costatum and Rhizosolenia delicatula) are seasonally associated with spring and fall blooms, with highest concentrations occurring near shore and close to large estuaries. The phytoflagellates are a diverse group (dinoflagellates, coacolithophores, cryptomonads, and euglenoids) which occur in high numbers during late spring and summer. The ultraplankton are a ubiquitous group primarily composed of unidentified round or oval non-flagellated cells in the 2-5 um size range.

Phytoplankton densities in Massachusetts Bay are lowest in winter, and peak during spring and fall blooms. Predominant species occurring in winter include various diatoms (Skeletonema costatum, Thalassiosira spp., Coscinodiscus spp.) and the dinoflagellate, Ceratium tripos. Spring (March - April) communities are characterized by the rapid development of high populations (blooms) of various diatoms (chiefly Thalassiosira spp., Chaetoceros socialis, and Detonula confervacea). Following the collapse of the spring bloom, small celled diatoms (Chaetoceros spp), coccoliths (Phaeocystis), unicellular chlorophytes (Carteria, Chlamydomonas), and the dinoflagellate Amphidium crassum may become important. Dominant groups during summer (July - August) include the diatoms (Rhizosolenia spp., Skeletonema costatum, Leptocylindrus spp.), unidentified phytoflagellates, and the nanoplankton (<10 um in size) (TRIGOM 1974; MWRA 1987). Ceratium spp. may be abundant in outer Massachusetts Bay during this time. From late August - October there is generally a continuous bloom of Skeletonema costatum. Blooms of the diatoms Leptocylindrus danicus and Rhizosolenia delicatula may also occur. S. costatum accounted for ca. 90% of the phytoplankton at MBDS in late September of 1973 (Martin and Yentsch 1973).

#### b. Primary Productivity and Chlorophyll a

Peak productivity in Massachusetts Bay is generally highest during the spring bloom period in March (Parker 1974, ref. by MWRA 1987). In general, phytoplankton productivity in northeast continental shelf waters is high between May and December, with bursts of high productivity also occurring in March and October. Lowest productivity occurs between late December and February (Sherman et al. 1988). Most of the production during the early spring bloom is attributable to diatoms, which dominate the netplankton (>20 um fraction). With the onset of water column stratification, diatoms are susceptible to sinkage below the euphotic zone, and the relative importance of nanoplankton increases. Recent studies indicate that nanoplankton (< 10 um fraction) account for ca. 70% of productivity in nearshore Massachusetts Bay waters during July - September (MWRA 1987). During the fall bloom period, netplankton (>20 um) once again increase in importance, but do not strongly dominate the community as in the spring (Sherman et al. 1988).

Estimated annual productivity in Massachusetts Bay waters is on the order of  $260 \text{ gC/m}^2$  per year (TRIGOM 1974, Sherman et al.; 1988).

Chlorophyll a concentration, a measure of algal biomass, also varies seasonally in Gulf of Maine inshore waters (Sherman et al. 1984). Highest values occur during the spring bloom and fall blooms, with lowest values occurring during June - August. Integrated total water column chlorophyll concentrations during the summer (July - early September) from shallow (< ca. 25 - 40m) Massachusetts Bay waters averages ca.  $40 - 75 \text{ mg/m}^2$  (TRIGOM 1974; MWRA 1987). Summer chlorophyll a concentrations (and productivity) in Massachusetts Bay appear to decrease with increasing distance from shore (MWRA 1987), and thus may be somewhat lower at MBDS. During the summer, when the water column at MBDS is stratified (Martin and Yentsch 1973), a pronounced subsurface chlorophyll a maxima is likely to be associated with the thermocline (cf. Sherman et al. 1988).

Although chlorophyll a concentrations are low during the summer relative to spring and fall levels, primary production in coastal waters generally remains high. High productivity, despite low chlorophyll a levels, occurs in summer because 1) small, relatively efficient nanoplankton dominate the phytoplankton and 2) the availability of photosynthetically active radiation is high (Sherman et al. 1988).

#### b. Zooplankton

The zooplankton community of Gulf of Maine waters (including Massachusetts Bay) is generally dominated by the ubiquitous copepods, Calanus finmarchicus, Centrophages typicus, and Pseudocalanus minutus. C. finmarchicus is the dominant species from spring through early autumn, when C. typicus becomes dominant (Sherman et al., 1988). C. finmarchicus and P. minutus are herbivorous, C. typicus is omnivorous, but prefers zooplankton prey (TRIGOM 1974). Other typical components of the zooplankton community include the copepod Metridia lucens, the euphausiid Meganycitiphanes norvegica, and the chaetognath Sagitta elegans. Further information concerning the seasonal composition of the Massachusetts Bay zooplankton community is provided by TRIGOM (1974). Ichthyoplankton (fish eggs and larvae) are discussed in Section 3.C.2.

Zooplankton biomass (as measured by displacement volume) in coastal Gulf of Maine waters peaks in July and October (Sherman et al., 1988). Overall, in the Gulf of Maine, peak zooplankton biomass occurs in May with a gradual decline through autumn.

Microzooplankton (zooplankton capable of passing through a 333-um mesh net) are also an important component of the Gulf of Maine zooplankton community. Principal components of the microzooplankton include immature copepods (eggs, naupuli and copepodites), and members of the copepod genus Oithona. The microzooplankton component is most abundant in summer and autumn; zooplankton encountered in winter and early spring are primarily adults. Microzooplankton biomass in northeast shelf waters may be ca. 30% of the biomass retained by a standard 333 um net.

### 3.C.2 FINFISH AND SHELLFISH RESOURCES

The fisheries resources at the Massachusetts Bay Disposal Site were evaluated using information from a variety of sources. General information concerning the fishes of Massachusetts Bay was obtained from Bigelow and Schroeder (1953), Clayton *et al.* (1978), Grosslein and Azarovitz (1982), TRIGOM (1974), and various Massachusetts Division of Marine Fisheries (MDMF) and National Marine Fisheries Service (NMFS) reports (e.g. Lux and Kelly 1978; Howe *et al.* 1986). Catch data from NMFS and MDMF bottom trawl surveys were obtained to provide information concerning the fisheries resources in the vicinity of the MBDS. Data from 26 trawls taken within six nautical miles of the MBDS site (during 1979 - 1984, at water depths > 60 m) are presented in this report. Trawls were from NMFS strata 26 and 66, and MDMF strata 36. Most trawls (22 of 26) were from either spring or fall surveys. The mean starting point of NMFS trawls, and the mid point of MDMF trawls was, respectively, 4.1 and 4.6 nautical miles from the MBDS center point. Average water depths at the starting point of NMFS trawls and midpoint of MDMF trawls were, respectively, 76 and 72 meters. Site specific information for individual trawls are presented in the Appendix II (Table AII-1) NMFS surveys utilized # 36 or # 41 (one case) Yankee otter trawls with 0.5 inch codend liners (Grosslein and Azarovitz 1982; Azarovitz, pers. comm.; NMFS 1982, 1985). MDMF surveys utilized 0.75 inch North Atlantic trawls lined with 0.25 inch codend liners (see Howe *et al.*, 1984, 1986). Duration of MDMF and NMFS trawls was, respectively, 20 and 30 minutes, at speeds of 2.5, and 3.5 knots.

Site specific information concerning the fisheries resources at MBDS was obtained using gill nets, trammel nets, bottom trawls, submersible video observations, and interviews with local fishermen. Studies were conducted between June, 1985 and February, 1986 (Table 3.C.2-1). Methods employed in the 1985 studies are described in SAIC (1987). Bottom trawls in February of 1986 were 40 minutes in duration, at a speed of three knots.

The Benthic Resources Analysis Technique (BRAT; Lunz and Kendall, 1982) was employed to examine trophic relationships between benthic invertebrates and demersal fish at MBDS. The technique involves comparing the prey of demersal fish (as indicated by stomach content analysis) with prey availability (biomass) as determined by quantitative benthic samples. Fish and benthic samples for the BRAT analysis were taken in the Fall of 1985 within MBDS and at a nearby muddy reference location. Benthic samples from MBDS were taken from dredged material deposited 6-12 months previously, and relatively undisturbed natural mud bottom. Methods employed are fully described in SAIC (1987).

## Finfish Community Composition

### General

The Gulf of Maine supports resident or migratory populations of approximately 200 species of fish (Bigelow and Schroeder 1953). General accounts of fish community composition in Massachusetts nearshore and/or offshore waters are provided by Lux and Kelly (1978, 1982), Grosslein and Azarovitz (1982), and Howe *et al.* (1984). The relatively common species likely to occur in Massachusetts Bay, near the vicinity of the MBDS, are listed in Table 3.C.2-2. All of these species are widely distributed in the Gulf of Maine and/or North Atlantic waters south of Cape Cod.

Although the majority of species likely to be present in the vicinity of MBDS are year round residents in Massachusetts Bay, 12 species are seasonal (mostly summer) migrants. Approximately 80 % of the species likely to occur near the MBDS are demersal, semi-demersal, or semi-pelagic. Twenty three species, including 10 seasonal migrants, are of importance to commercial and/or sport fisheries (Table 3.C.2-2).

### NMFS and MDMF Studies

NMFS and MDMF bottom trawls within six nautical miles of the MBDS center point captured 36 species of fish (Table 3.C.2-3). The most frequently occurring species in spring and fall surveys were American plaice, witch flounder, red hake, silver hake, Atlantic cod, ocean pout, and longhorn sculpin (Table 3.C.2-4). Size (length) of captured fish indicate that both juveniles and adults of most species were present.

Yields from bottom trawls are summarized in Tables 3.C.2-5 - 8 (data from individual trawls are presented in Appendix II (AII-3)). American plaice was numerically predominate throughout the year, and generally accounted for the largest percentage of total catch by weight. American plaice is one of the most common species captured in bottom trawls in Massachusetts Bay (Lux and Kelly, 1978, 1982). With the possible exception of witch flounder, it is reportedly the most abundant flatfish in the Gulf of Maine at depths greater than ca. 55 m (Bigelow and Schroeder, 1953).

Principal subdominates in NMFS/MDMF spring trawl included Atlantic cod, ocean pout, and witch flounder. Subdominates in fall included silver hake, red hake, Atlantic cod, and Atlantic herring. All these species are common in Massachusetts Bay (Lux and Kelly, 1978, 1982), and most are of considerable commercial importance.

Trawl yields indicate that a moderately productive fishery exists in the vicinity of MBDS. Mean weight of fish caught in spring and fall trawls was 136 kg. Weight of fish caught did not vary significantly between seasons (spring vs fall) or, despite gear differences, between NMFS and MDMF surveys (Appendix II - Table AII-4). MDMF trawls caught a



significantly greater number of fish per trawl ( $p < 0.04$ ). Catch averaged 1075 fish in MDMF trawls and 400 fish in NMFS trawls. Mean number of fish caught per trawl in spring and fall were not significantly different.

#### COE Studies at MBDS

Studies conducted by the COE during 1985-1986 documented the occurrence of 32 fish species at the Massachusetts Bay Disposal Site (Table 3.C.2-3). Overall, these studies suggest that American plaice, witch flounder, and redfish are the predominate non-migratory demersal species present at MBDS. Principal seasonal migrants are silver hake, red hake, and spiny dogfish.

In June most (ca. 90%) of fish caught in gill nets were spiny dogfish (Table 3.C.2-9). Spiny dogfish are seasonal migrants to the Gulf of Maine and schools are common in Massachusetts Bay during the spring and fall (Bigelow and Schroeder 1953). Commercial fishermen indicate that dogfish typically arrive in the vicinity of MBDS in late May through early June. Because transient dogfish schools undoubtedly greatly disturbed the fish community at MBDS, COE surveys in June may poorly represent the normal (pre dogfish) spring community.

Fish noted at MBDS in June submersible observations included snake-blenny, ocean pout, flounder, and sculpin (Table 3.C.2-10). Snakeblenny, a small demersal fish, was most common on mud/clay substrate. Ocean pout and sculpins were predominate on cobble. Sandlance larvae were noted on mud/clay bottom.

Gill net catches on dredged material in October were dominated by redfish. Silver hake, red hake, thorny skate, and Atlantic cod were the principal subdominates (Table 3.C.2-11). Trammel nets set on hard bottom NE of MBDS captured primarily winter flounder. Silver hake, thorny skate and Atlantic wolffish were also captured.

Predominate species caught in October COE bottom trawls within MBDS, and at the reference location, were American plaice, witch flounder, silver hake, red hake, and redfish (Table 3.C.2-12).

Predominate species captured in February COE trawls at MBDS were American plaice, cusk, ocean pout, redfish, witch flounder and silver hake (Table 3.C.2-12). Because both mud bottom and cobble were trawled, species characteristic of both habitat types were obtained.

Species reported from MBDS by fishermen, but not otherwise noted in COE studies, were bluefish and bluefin tuna. Both are pelagic, summer migrants to Gulf of Maine.

American plaice was the most common species captured in both COE and NMFS/MDMF bottom trawls. Subdominates in NMFS and/or MDMF surveys (i.e. witch flounder, silver hake, red hake, ocean pout, Atlantic cod) were also

present at MBDS. Overall, COE studies and NMFS/MDMF trawls documented the occurrence of 41 species in the vicinity of MBDS (Table 3.C.2-3). Thirty two species (78 %) were noted in COE studies. Nine species were reported from NMFS/MDMF trawls, but not from MBDS in COE studies. Most of these species were uncommon, and typically accounted for < 1 % of catch (by number) in NMFS/MDMF trawls.

#### Dredged Material vs Natural Bottom at MBDS

Although the design of this study does not allow a rigorous evaluation of fish communities at MBDS on dredged material versus relatively undisturbed substrates, some comparisons are possible. Submersible observations suggest that dredged material recently deposited within MBDS may support fewer fish than natural mud or cobble bottom (Table 3.C.2-10). The absence of replicate samples and the possible impact of spiny dogfish, however, limit the value of these data. Similarly, although gill nets in June caught more fish on natural bottom, the catch was dominated by spiny dogfish.

Replicated (n=2) bottom trawls in October within MBDS (on both dredged material and natural bottom) and a nearby reference location caught similar numbers of fish (Table 3.C.2-12). Mean catch weight, however, was significantly lower within MBDS ( $p < 0.05$ ;  $T = 3.68$ ). Although American plaice was the most abundant species (by number) at both locations, the relative importance of other species at the two sites varied. Witch flounder and redfish were principal subdominates within MBDS material, while silver and red hake were the principle sub- or codominates at the reference location. Mean length of American plaice caught within MBDS was slightly less than for those caught at the reference location (26.7 vs. 25.4 cm; see also Figure III.A-13, Vol 2 SAIC, 1987). This difference was not quite statistically significant ( $0.5 < p < 0.10$ ;  $df = 291$ ).

#### Commercial Fisheries Near MBDS

A viable commercial fishery exists in the vicinity of MBDS (Figure 3.C.2-1). Catch is dominated by American plaice and witch flounder. Wolfish, redfish, cusk, haddock, and pollock are caught in lesser amounts. Witch flounder and American plaice are caught throughout the year on soft bottom. Redfish and wolffish are occasionally caught on or near patches of hard bottom. Directed fisheries capture silver hake in the fall and pollock in the winter. There is also a directed fishery for spiny dogfish on Stellwagen Bank during summer and fall. Winter flounder and yellowtail flounder are caught near the MBDS but are more abundant in shallower inshore waters. Cod are caught as a by-catch or by directed fisheries in late winter and spring. Herring are caught on Stellwagen Bank and in Massachussettes Bay, southwest of MBDS.

Target species of sportfisherman near MBDS include cod, cusk, haddock, mackerel, bluefish, and bluefin tuna. Wolffish, flounder, and pollock are also caught.

Stocks of American plaice, witch flounder, Atlantic cod, Atlantic herring, haddock, redfish, silver hake, and red hake in the Gulf of Maine are currently depressed, or in decline (NOAA, 1987).

NMFS commercial catch statistics from the vicinity of the MBDS indicate that the area supports a productive fishery resource. Average finfish and shellfish yields for 1982-1984 from the NMFS "10 minute square" which includes the MBDS was 6,316,000 kg (Table 3.C.2-13). Although this 10' square represents < 3 % of the NMFS statistical area (514) which includes Cape Cod Bay, Massachusetts Bay, and Stellwagen Bank, it accounted for 11 % of total landings for the area in 1984 (see Section 3.D.1).

#### Occurrence of Spawning and Fish Eggs and Larvae at MBDS

##### Spawning

At any given time a number of different species are likely to be spawning at or near MBDS (Table 3.C.2-14). Most of these species spawn during a period of several months, and over a wide geographical area.

Common species which spawn in open water near MBDS include American plaice, silver hake, witch flounder, and Atlantic mackerel. MBDS is within the principal spawning grounds of silver hake and pollock (TRIGOM 1974). At its closest point, the major spawning ground for Atlantic cod in Massachusetts Bay is ca. 8 n.m. southwest of MBDS (Bigelow and Schroeder 1953).

Most species likely to deposit demersal eggs at MBDS spawn preferentially on hard bottom. These include longhorn sculpin, American sand lance, wolffish, radiated shanny, ocean pout, rock gunnel, and Atlantic herring. Principal spawning areas for Atlantic herring, however, are located in the Gulf of Maine well north of MBDS and on Stellwagen Bank (Graham *et al.* 1972; TRIGOM 1974). Species which may deposit eggs on soft bottom near MBDS include snakeblenny, wrymouth, and alligatorfish.

Most species which spawn in fall and winter deposit eggs demersally (Table 3.C.2-14). Spring and summer spawners generally deposit eggs in open water. Incubation periods vary widely. Demersal eggs deposited in fall and winter generally have long incubation periods relative to pelagic eggs deposited by spring and summer spawners. Larvae of most species which spawn in the vicinity of MBDS are, at least initially, pelagic.

##### Fish Eggs and Larvae

Although specific data concerning the occurrence and abundance of fish eggs and larvae at MBDS are lacking, information is available from nearby coastal stations at Seabrook, New Hampshire (Normandeau, 1985) and Plymouth, Massachusetts (Boston Edison, 1986). Given the proximity of these sites to MBDS, and water circulation patterns in the Gulf of Maine,

it is likely that these data will, at least, qualitatively, identify seasonal ichthyoplankton peaks at MBDS. The lack of more precise information concerning ichthyoplankton at MBDS cannot readily be addressed. Because of tremendous inate variability, an intensive sampling effort, over many years, would be required to establish meaningful baseline levels for ichthyoplankton at MBDS.

Highest concentrations of planktonic eggs occur from June through August at Seabrook (Table 3.C.2-15), and during June and July at Plymouth (Figure 3.C.2-2). Eggs of cunner, yellowtail flounder, mackerel, hakes (*Urophycis* spp.), and rockling are predominant during the summer peak at both Seabrook and Plymouth. Although concentrations of planktonic eggs are low from October through April, substantial numbers of demersal eggs may be present at this time, in suitable habitats. Among demersal spawners, eggs of American sandlance and Atlantic herring are probably predominate in the Gulf of Maine during the fall and winter.

Planktonic larvae are most abundant at Seabrook during July and August (Table 3.C.2-16). Atlantic mackerel and cunner are the predominate species at this time. Secondary peaks dominated by American sandlance (February-April) and Atlantic herring (October-November) also occur.

Planktonic larvae exhibit a weakly bimodal distribution at Plymouth (Figure 3.C.2-3), with peaks occurring in April and June. American sandlance and sculpins (*Myoxocephalus* spp.) are predominate in spring, while Atlantic mackerel, cunner and rockling are predominant in summer.

Additional information concerning the abundance and distribution of planktonic larval fish in the Gulf of Maine is provided by MARMAP surveys (Morse *et al.*, 1987). Overall, in the Gulf of Maine, American sandlance, Atlantic herring, Atlantic mackerel, cunner, and redfish larvae are most abundant. The seasonal occurrence and peak concentrations of predominant species in Massachusetts Bay are presented in Table 3.C.2-17. Highest reported concentrations are of American sandlance (December - April), Atlantic mackerel (May-June), and Atlantic herring (September - November).

## Food Utilization

### General

Various reports detail the food habits of common fish of the Gulf of Maine (e.g. Bigelow and Schroeder 1953; Michaels and Bowman 1976; Shettling *et al.*, 1980; Michaels and Bowman 1983, Bowman, 1981). Most species exhibit some degree of preference for certain prey groups. Feeding preferences may vary with season, geographic location, and the relative abundance of available prey items. Juvenile and adult conspecifics may utilize different food resources.

Fish at MBDS can be divided into three primary feeding guilds (Table 3.C.2-18). Planktivorous species such as American sandlance, Atlantic

mackerel, and herring primarily utilize small crustaceans (i.e. copepods, euphausiids, mysids), and fish and invertebrate eggs and/or larvae. Nektonic feeders prey primarily upon larger pelagic crustaceans and/or fish. Many nektonic feeders (e.g. silver hake, spiny dogfish) in Massachusetts Bay are summer migrants. Redfish is the principal resident nektonic feeder in the vicinity of MBDS. Demersal or semi-demersal feeders utilize a wide variety of benthic prey species (i.e. crustaceans, molluscs, echinoderms, polychaete worms, and fish). Virtually all members of the demersal/semi-demersal guild are year round residents at MBDS. Cunner and Atlantic cod feed, depending on prey availability, either demersally or on nekton.

#### MBDS

Feeding preferences of selected species caught at MBDS in October are summarized in Table 3.C.2-19 (see also Tables III-5 through III-9, SAIC, 1987). American plaice preyed chiefly upon echinoderms (brittle stars), and to a much lesser extent bivalves and crustaceans. Principal prey items of witch flounder were Chaetozone, Spio, Sternopsis, and Tharyx. Atlantic cod preyed chiefly upon benthic amphipods, polychaetes, and other crustaceans. Winter flounder preyed chiefly upon polychaetes and amphipods. Hakes captured in fall were feeding exclusively on pandalid shrimp.

Stomach contents of small numbers of other species captured in June or October are presented in Volume 2 of the SAIC (1987) technical report. Among these, clearnose skate (n=3), and fourbeard rockling (n=3) were feeding primarily on crustaceans. Atlantic wolffish (n=2) were feeding primarily on molluscs and crustaceans. Redfish (n=5) captured in June preyed exclusively upon crustaceans (principally mysids).

Prey preferences of other relatively common demersal species at MBDS must be inferred from the literature. Ocean pout prey primarily upon echinoderms, and to a lesser extent on molluscs and crustaceans. Snake-blenny apparently feed on small crustaceans, echinoderms, and bivalves (Bigelow and Schroeder 1953). Cusk prey upon molluscs, crabs, and infrequently on echinoderms (Clayton et al. 1978).

#### BRAT Analysis

The analysis of feeding strategy groups focused primarily on American plaice and witch flounder, the most common finfish at MBDS, and the reference location. These species preyed predominantly upon benthic invertebrates. Fish were placed into three primary feeding strategy groups based on prey size preference as determined from stomach content analysis (Table 3.C.2-20; see also Figures III.A-23, Vol I-SAIC, 1986). Composition of these groups (and several subgroups) are presented in Table 3.C.2-20. Group I consisted primarily of small (10-14.9 cm) American plaice and witch flounder feeding on small prey at MBDS. Group III consisted of large plaice or witch flounder feeding on large prey at

either MBDS or the reference location. Group II generally consisted of intermediate sized fish which exploited a range of prey sizes at both MBDS and the reference location. Witch flounder of similar size were generally feeding on smaller prey at MBDS than at the reference area. American plaice size classes showed similar prey exploitation behavior at MBDS and the reference area. Feeding efficiency, as indicated by the mean weight of food per stomach, was greater for intermediate sized plaice and witch flounder feeding at MBDS relative to those feeding at the reference area (Table 3.C.2-21).

Food availability was analyzed as biomass within feeding depth strata. Biomass of potential prey within MBDS (dredged material and natural bottom) and at the reference location is summarized in Figure 3.C.2-4. Total prey biomass available at the three sites was similar. Dredged material and natural bottom at MBDS, however, yielded much greater quantities of small prey relative to the reference area. Prey biomass on dredged material, and to a lesser extent on natural bottom at MBDS, was concentrated near the surface (see Table III.A-12, Vol. 1 SAIC, 1987).

Prey biomass available to the various feeding strategy groups is summarized in Figure 3.C.2-5. Dredged material yielded greater quantities of prey biomass available to Group I, and II than did natural bottom within MBDS, or at the reference location. Relative to dredged material however, the reference location and natural bottom within MBDS provided greater amounts of prey biomass for Group III fish.

In conclusion, the BRAT analysis suggests that disposal activities at MBDS may have enhanced food resource availability for relatively small American plaice and witch flounder. Disposal of dredged material, and resulting changes in prey size distribution, may have reduced habitat suitability for larger (> 20 cm) American plaice.

#### Shellfish Resources

Only limited information is available concerning shellfish resources in the vicinity of MBDS. General distribution maps indicate that northern lobster (Homarus americanus), sea scallops (Placopecten magellanicus), longfin squid (Loligo pealei), shortfin squid (Illex illecebrosus) and ocean quahog (Arctica islandica) occur in eastern Massachusetts Bay (Grosslein and Azarovitz 1982). NMFS/MDMF bottom trawls near MBDS captured these species, and also small numbers of rock crab (Cancer irroratus), and jonah crab (Cancer borealis) (Table 3.C.2-22).

COE bottom trawls near or within MBDS caught few lobsters. Trawls within MBDS (n=2) in October captured only one lobster. No lobsters were caught from trawls (n=2) at the reference location. Shrimp Pandalus borealis were caught at both MBDS and the reference location. COE bottom trawls (n=2) at MBDS in February captured lobsters (3), red crab (Geryon quinquedens) (2), a toad crab (Hyas araneus), an unidentified scallop, and numerous shrimp.

Ocean quahogs were present in grab samples from mud and sand reference stations near MBDS in January of 1986 (see Table III-1 SAIC, 1987). Densities were  $174/m^2$  on sand and  $3/m^2$  on mud. No ocean quahogs, however, were noted within MBDS on natural bottom or on dredged material. Sea scallops were absent from grab samples, but were noted in submersible observations on cobble (within MBDS) at low densities ( $0.01/m^2$ ). Submersible observations also noted pandalid shrimp within MBDS. Densities ranged from  $7.27/m^2$  on mud-clay to  $1.38/m^2$  on cobble (Vol I; Table III.B-19 SAIC, 1987). Density of shrimp on dredged material ( $2.50/m^2$ ) was lower than average (weighted) density at two mud-clay sites ( $6.4/m^2$ ).

Among other prey, Atlantic cod and wolffish captured in COE studies at MBDS in October had consumed northern shrimp (*Pandalus borealis*). Wolffish had also consumed jonah crab (see Table III-9 Vol. II SAIC, 1987).

MBDS is currently recommended closed to commercial shellfishing by FDA. A lobster fisherman, however, indicated that good yields of apparently high quality lobsters are possible at MBDS. The fisherman reported that lobsters were absent from MBDS in the summer through September.

General information concerning habitat preference and life history of commercially important shellfish species at MBDS is presented in Table 3.C.2-23. Several species show pronounced seasonal movements. Short-fin squid, and long-fin squid are summer migrants, and likely to be absent at MBDS from late fall through spring. Northern shrimp show a pronounced shoreward migration in fall. Lobsters are likely to be present during late fall, winter and early spring, but absent during the summer.

Spawning by squid, or release of newly hatched larvae by northern shrimp and lobsters, does not occur in the vicinity of MBDS. Ocean quahog eggs and larvae may occur near MBDS from June through fall. Sea scallop eggs and larvae may occur near MBDS from September through November. Crabs mate near MBDS from fall through early summer. Larval crabs may be present at MBDS during spring, summer, or early fall.

Summary These studies suggest that substantial finfish resources are likely to occur in the vicinity of MBDS. The demersal (resident) finfish community on mud bottom at MBDS is dominated by American plaice and witch flounder. Silver and red hake are abundant, commercially important, seasonal migrants at MBDS. Hard bottom communities at MBDS (approximately 25 % of total area) are probably dominated by redfish, ocean pout, cusk, and atlantic wolffish.

Studies suggest that some differences may exist between fish communities on dredged material versus natural bottom. Also, food resource availability and food utilization patterns of dominant demersal fish may have been altered by previous dredged material disposal.

Peak concentrations of planktonic fish eggs at MBDS are likely to occur during the late spring and early summer. Larval abundance probably has a bimodal distribution, with peaks occurring in spring and summer.

Shellfish resources at MBDS are less well documented. At present, although few lobsters were noted in bottom trawls, it is felt that considerable numbers may be present during the late fall, winter, and spring. Other commercially important shellfish, including squid, northern shrimp, rock crab, and ocean quahog occur at or near MBDS.

Although COE studies appear to adequately characterize the major components of the fisheries community at MBDS, the limitations of this study should be recognized. Highly reliable data from MBDS are available only for October of 1985. Since stocks of many finfish (and shellfish) can experience considerable seasonal (Grosslein and Azarovitz 1982) and year to year variation (e.g. NOAA 1987), recommendations concerning disposal at MBDS based on these data should be conservative.

Our knowledge of the finfish and shellfish community is based largely on sampling techniques which are biased towards certain demersal, semi-demersal or semi-pelagic species. Also, yields of bottom trawls, gill nets, and even submersible observations reflect upon not only absolute abundance of fish species, but also their relative "catchability". Fortunately a sampling bias towards demersal species is tolerable, since these species are likely to be most effected by disposal activities.



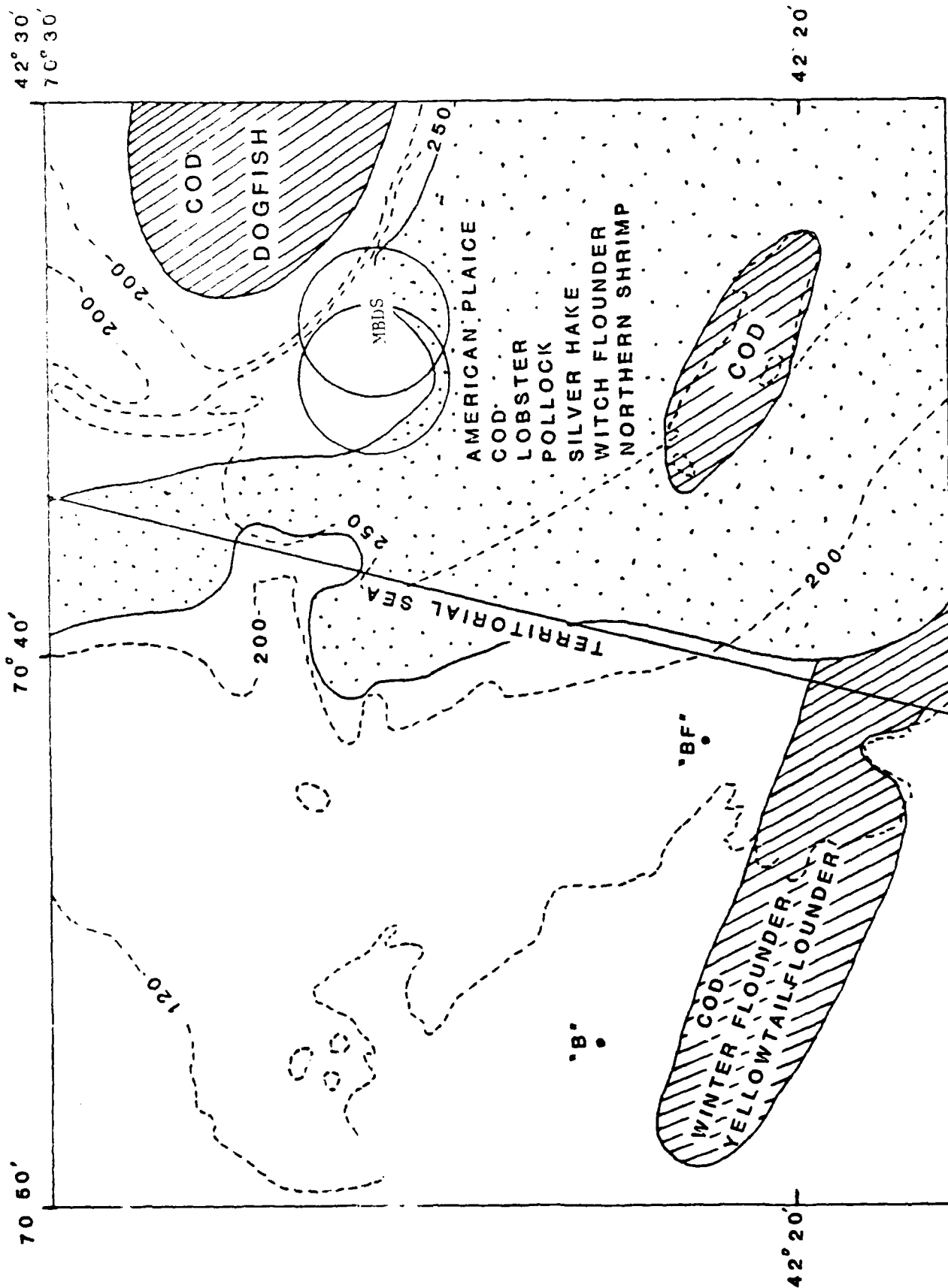


Figure 3.C.2-1 Dragging grounds in the disposal area. The area fishable with light ground tackle is stippled. Three areas with rougher bottom are cross-hatched. Contours are in feet. No fishing is allowed inside MBDS

Figure 3.C.2-2: Concentration of planktonic fish eggs in Cape Cod Bay, near Plymouth, MA (1975 - 1985).

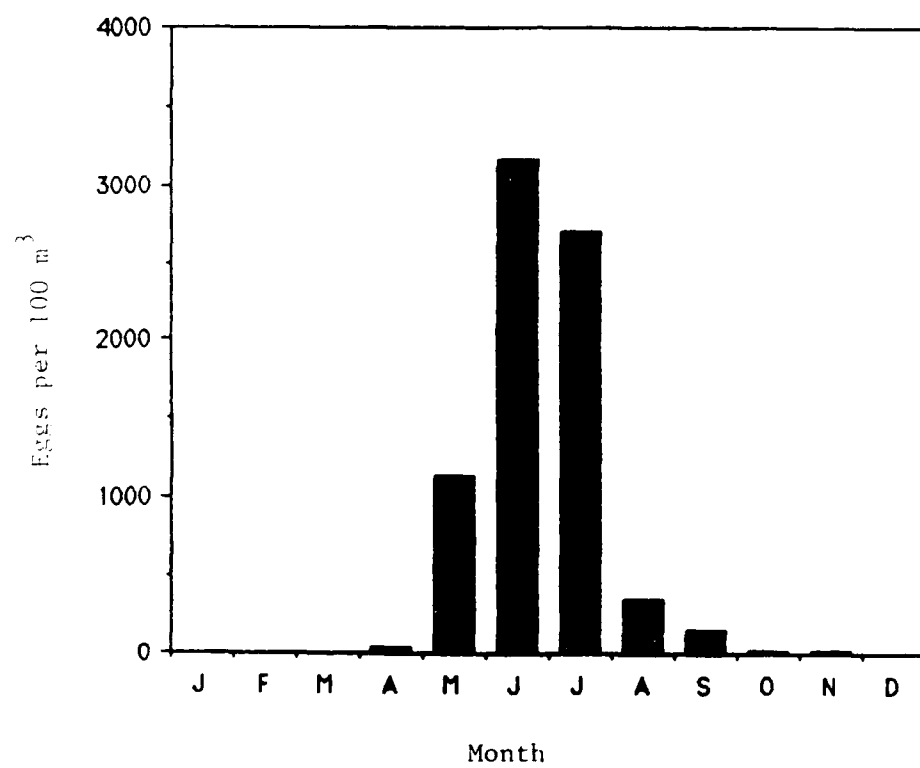


Figure 3.C.2-3: Concentration of planktonic fish larvae in  
Cape Cod Bay, near Plymouth, MA (1975 - 1985)

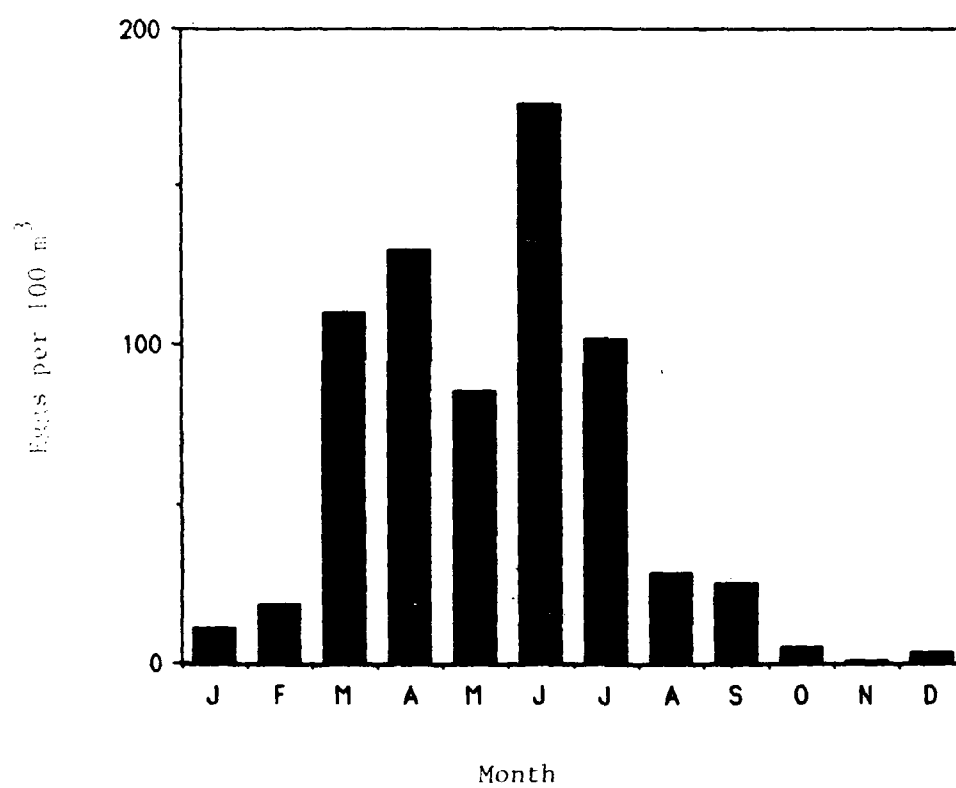


Figure 3.C.2-4: Biomass of potential invertebrate prey at MBDS

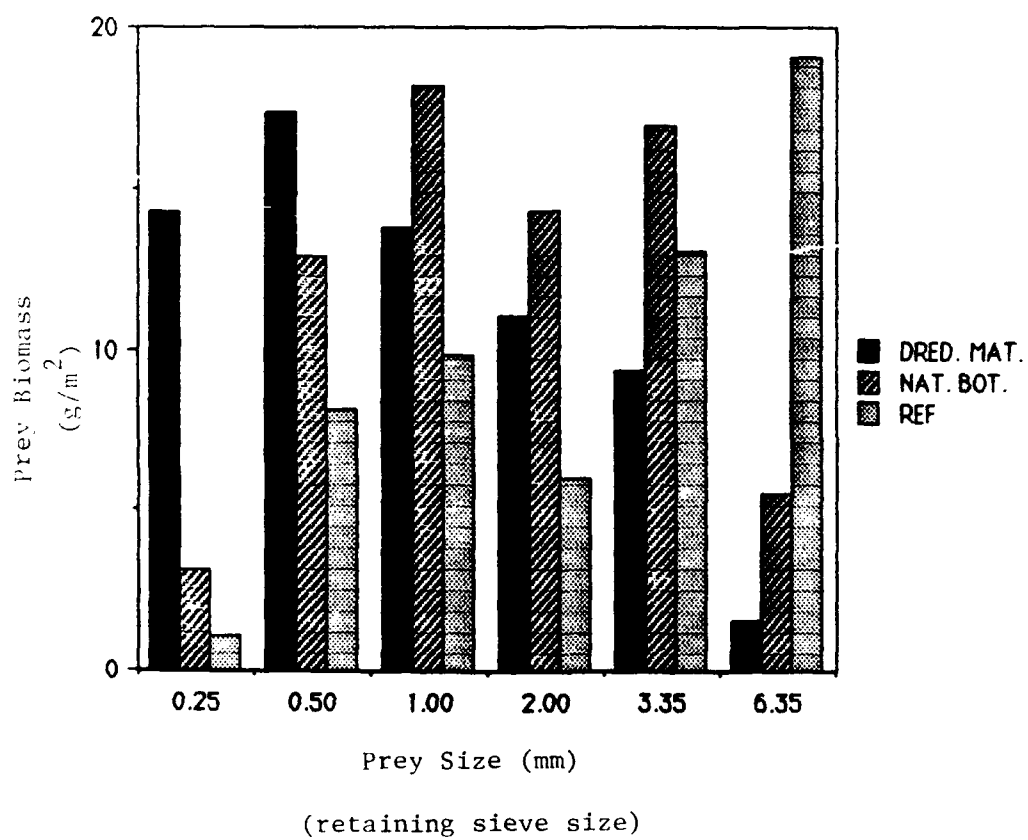


Figure 3.C.2-5: Prey biomass available to feeding strategy groups at MBDS

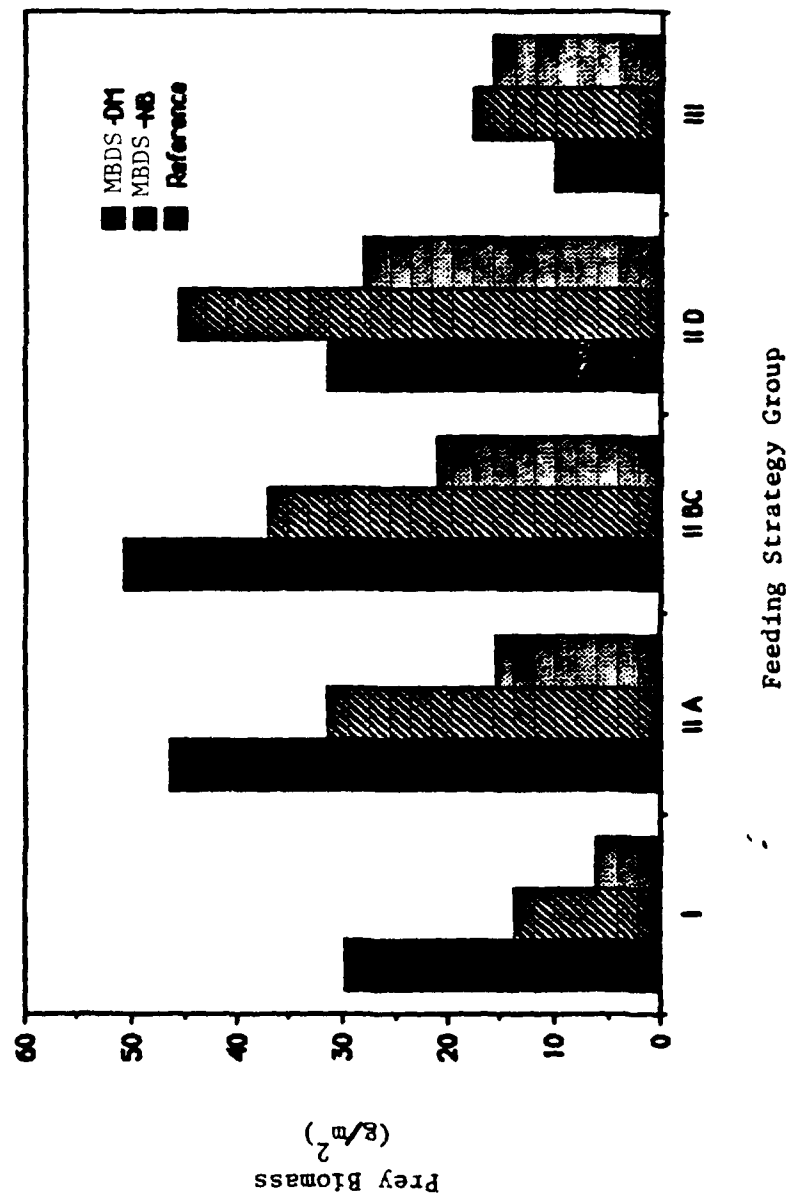


Table 3.C.2-1: Summary of COE fisheries studies at the Massachusetts Bay Disposal Area (1985-1986).<sup>a</sup>

| Methodology              | 1985 |                   |                | 1986 |      |
|--------------------------|------|-------------------|----------------|------|------|
|                          | June | October           | February       | DM   | NB   |
|                          | DM   | NB                | REF            |      |      |
| Gill Nets                | R(2) | R(4)              | X <sup>b</sup> |      |      |
| Trammel Nets             | X    | X                 | X <sup>b</sup> |      |      |
| Bottom Trawls            |      | R(2) <sup>c</sup> | R(2)           |      | R(2) |
| Submersible Observations | X    | R(3)              |                |      |      |
| BRATT Analysis           |      | X                 | X              |      |      |

a. Locations and substrate characteristics of 1985 sample sites are presented in SAIC(1987) (Figures III.A-1 and I.2-18). 1986 bottom trawls sampled both natural mud and hard bottom within MBDS

DM: dredged material; NB: natural bottom; REF: reference location outside of the MBDS.; R: replicate (n) samples

b. Multiple nets tied together

c. Area trawled was principally within, MBDS and included both natural bottom and dredged material.

Table 3.C.2-2: Common Fish Species of the Gulf of Maine Likely to Occur in the Vicinity of the Massachusetts Bay Disposal Area

| Common Name        | Scientific Name           | Distribution <sup>b</sup>    | Habitat <sup>c</sup> | Substrate Preferred | Economic Value <sup>e</sup> |
|--------------------|---------------------------|------------------------------|----------------------|---------------------|-----------------------------|
| Spiny dogfish      | Squalus acanthias         | nearshore to offshore (sm)   | P-D                  |                     |                             |
| Little skate       | Raja erinacea             | nearshore to offshore        | D                    | P.S.M               |                             |
| Barndoor skate     | R. laevis                 | nearshore to offshore        | D                    | SM.S.G              |                             |
| Winter skate       | R. ocellata               | nearshore to offshore        | D                    |                     |                             |
| Thorny skate       | R. radiata                | offshore to oceanic, bk, bs  | D                    | S.G.SH SM           | C                           |
| Blueback herring   | Alosa aestivalis          | estuarine to coastal (sm)    | P                    |                     | C.S                         |
| Alewife            | A. pseudoharengus         | freshwater to coastal (sm)   | P                    |                     | S                           |
| American shad      | A. sapidissima            | freshwater to coastal (sm)   | P                    |                     | C                           |
| Atlantic menhaden  | Brevortia tyrannus        | coastal (sm)                 | P                    |                     | C                           |
| Atlantic herring   | Clupea harengus           | coastal, bk                  | P                    |                     | C                           |
| Goosefish          | Lophius americanus        | nearshore to oceanic         | D                    | HS.P.G.S.SH.SM      |                             |
| Fourbeard rockling | Enchelyopus cimbrius      | nearshore to offshore        | D                    | SMS                 |                             |
| Atlantic cod       | Gadus morhua              | coastal to oceanic, bk       | D-P                  | R.S.SH.G            | C.S                         |
| Haddock            | Melanogrammus aeglefinis  | coastal to offshore          | D-P                  | G.CL.S.SH           | C.S                         |
| Silver hake        | Merluccius bilinearis     | coastal to offshore (sm)     | P-D                  | S.G.M               | C                           |
| Pollock            | Pollachius virens         | coastal, bk                  | P-D                  |                     | C.S                         |
| Red hake           | Urophycis chuss           | nearshore to oceanic (sm)    | D                    | SB                  | C                           |
| White hake         | U. tenuis                 | nearshore to oceanic (sm)    | D                    | SB                  | C                           |
| Cusk               | Brosme brosme             | coastal to oceanic, bk       | D                    | R                   | S                           |
| Ocean pout         | Macrozoarces americanus   | nearshore to coastal, bk, bs | D                    | S.G.R               | C                           |
| Bluefish           | Pomatomus saltatrix       | nearshore to offshore (sm)   | P                    |                     | S                           |
| Scup               | Stenotomus chrysops       | nearshore to offshore (sm)   | D                    | SM.R                |                             |
| Cunner             | Tautoglabrus adspersus    | nearshore to offshore, cbk   | D                    | R                   |                             |
| Snakeblenny        | Lumpenus lumpretaeformis  | nearshore to offshore        | D                    | M.HB                |                             |
| Daubed shanny      | L. maculatus              | offshore, bs                 | D                    |                     |                             |
| Radiated shanny    | Ulvaria subbifurcata      | nearshore to coastal, bs     | D                    | HB                  |                             |
| Wrymouth           | Cryptacanthodes maculatus | nearshore to offshore bs     | D                    | SM                  |                             |

Continued on next page.

Table 3.C.2-2: continued.

| Common Name         | Scientific Name               | Distribution <sup>b</sup>    | Habitat <sup>c</sup> | Substrate <sup>d</sup><br>Preference | Economic<br>Value <sup>e</sup> |
|---------------------|-------------------------------|------------------------------|----------------------|--------------------------------------|--------------------------------|
| Rock gunnel         | Pholis gunnellus              | nearshore to offshore, cbk   | D                    | P, G, R                              |                                |
| Atlantic wolfish    | Anarhichas lupus              | nearshore to offshore        | D                    | HB                                   |                                |
| American sandlance  | Ammodytes hexopterus          | nearshore, bank edges        | D                    | S                                    |                                |
| Atlantic mackerel   | Scomber scombrus              | coastal to offshore (sm)     | P                    |                                      | C, S                           |
| Bluefin tuna        | Thunnus thynnus               | coastal to oceanic (sm)      | P                    |                                      | C, S                           |
| Butterfish          | Peprilus triacanthus          | nearshore to offshore (sm)   | P-D                  |                                      |                                |
| Redfish             | Sebastes marinus              | nearshore to oceanic, bk, bs | D                    | R, HB, M                             |                                |
| Northern searobin   | Prionotus carolinus           | nearshore to offshore        | D                    | SHB                                  |                                |
| Sea raven           | Hemitripterus americanus      | nearshore to offshore        | D                    | HS, R, P, HC                         |                                |
| Shortthorn sculpin  | Myoxocephalus scorpius        | nearshore to offshore        | D                    | SB, M, S, P                          |                                |
| Longhorn sculpin    | M. octodecimspinosus          | nearshore to coastal         | D                    |                                      |                                |
| Alligatorfish       | Aspidophoroides moropterygius | estuarine to offshore, bk    | D                    |                                      |                                |
| Lumpfish            | Cyclopterus lumpus            | coastal, bk, bs              | D                    | P, S, SM                             |                                |
| Fourspot flounder   | Paralichthys oblongus         | nearshore to coastal         | D                    | R                                    |                                |
| Windowpane          | Scophthalmus aquosus          | coastal to offshore, bk      | D                    |                                      |                                |
| Witch flounder      | Glyptocephalus cynoglossus    | nearshore to coastal         | D                    | S                                    |                                |
| American plaice     | Hippoglossoides platessoides  | coastal to oceanic, bk, bs   | D                    | M, CL, MS                            | C                              |
| Yellowtail flounder | Limanda ferruginea            | coastal to oceanic, bk, bs   | D                    | S, M, SB                             | C                              |
| Winter flounder     | Pseudopleuronectes americanus | coastal to offshore, bk      | D                    | S, M-S                               | C                              |
|                     |                               | estuaries to offshore, bk    | D                    | SB, MS                               | C, S                           |

a. adapted from Bigelow and Schroeder 1953; BLM 1977; Clayton *et al.* 1978; Grosslein and Azarovitz 1982; and TRIGOM 1974.

b. Nearshore: to 15 m; Coastal: to 91 m; Offshore: 91 m to continental slope; oceanic: open ocean; bs: deep basins of the Gulf of Maine; bk: shallow offshore banks; cbk: coastal banks; sm: seasonal migrant to Gulf of Maine.

c. P: pelagic; D: demersal

d. C: commercially important; S: sportfish

e. G: clay; G: gravel; HB: hard bottom; HC: hard clay; HS: hard sand; M: mud; MS: muddy sand; M-S: mud-sand; P: pebbles; R: rock; S: sand; SB: soft bottom; SH: shells; SM: soft mud; SMS: smooth muddy sand



Table 3.C.2.3: Fish species occurring at or near MBDS.

| Species                              | This Study <sup>a</sup> | NMFS and MDMF Bottom Trawls <sup>b</sup> |
|--------------------------------------|-------------------------|--|
| <u>Pelagic</u>                       |                         |  |
| Atlantic herring                     | G                       | X  |
| Alewife                              | G                       | X  |
| Atlantic mackerel                    | G,I                     | X  |
| Bluefish                             | I                       |  |
| Bluefin tuna                         | I                       |  |
| Blueback herring                     |                         | X  |
| American shad                        |                         | X  |
| <u>Semi-Demersal or Semi-Pelagic</u> |                         |  |
| Silver hake                          | G,I,N,T                 | X  |
| Atlantic cod                         | G,I,T                   | X  |
| Redfish                              | G,I,T                   | X  |
| Spiny dogfish                        | G,S,T                   | X  |
| Haddock                              | I                       | X  |
| Pollock                              | I                       | X  |
| Butterfish                           |                         | X  |
| <u>Demersal</u>                      |                         |  |
| American plaice                      | G,I,T                   | X  |
| Thorny skate                         | G,N,T                   | X  |
| Red hake                             | G,T                     | X  |
| Fourbeard rockling                   | G,T                     | X  |
| Longhorn sculpin                     | G,T                     | X  |
| Atlantic wolffish                    | I,T <sup>c</sup>        |  |
| Cusk                                 | I,T                     | X  |
| Yellowtail flounder                  | I,T                     | X  |
| Witch flounder                       | I,T                     | X  |
| Winter flounder                      | I,N,T                   | X  |
| Ocean pout                           | S,T                     | X  |
| Snakebleny                           | S                       | X  |
| Sandlance                            | S                       | X <sup>d</sup>                           |
| White hake                           | T                       | X  |
| Windowpane                           | T                       | X  |
| Alligatorfish                        | T                       | X  |
| Wrymouth                             | T                       | X  |
| Goosefish                            | T                       | X  |
| Clearnose skate                      | T                       |  |
| Pipefish                             | T                       |  |
| Northern searobin                    | T                       |  |
| Winter skate                         |                         | X  |
| Fourspot flounder                    |                         | X  |
| Scup                                 |                         | X  |
| Sea raven                            |                         | X  |
| Cunner                               |                         | X  |
| Daubed shanny                        |                         | X  |
| Mailed sculpin                       |                         | X  |
| unidentified skate                   | S                       |  |
| unidentified flounder                | S                       |  |
| unidentified sculpin                 | S                       |  |

- a. species noted in COE surveys within the MBDS area and in nearby reference locations (1985-1986). G: gill net; I: interviews with commercial or sport fishermen; N: trammel net; S: submersible observations; T: bottom trawl.
- b. species captured by NMFS and/or MDMF trawls within 6 nautical miles of the MBDS at depths > 60 m. (1979 -1984).
- c. captured solely in reference location.
- d. American sandlance

Table 3.C.2-4. Frequency of occurrence of fish species in NMFS and MDMF bottom trawls in the vicinity of MBDS.<sup>a</sup>

|            | Spring Trawls   | Fall Trawls   |
|------------|---|---|
| Common     | American plaice (100)<br>Atlantic cod (100)<br>Yellowtail flounder (100)<br>Witch flounder (100)<br>Ocean pout (89)<br>Red hake (89)<br>Silver hake (78)<br>Longhorn sculpin (78)<br>Sea raven (66)<br>Winter flounder (66)<br>Blueback herring (66)<br>Alligator fish (66)<br>Daubed shanny (66) | American plaice (100)<br>Witch flounder (100)<br>Red hake (100)<br>Silver hake (100)<br>Alewife (84)<br>Ocean pout (77)<br>Longhorn sculpin (69)<br>Atlantic cod (69)<br>White hake (69)  |
| Occasional | Thorny skate (56)<br>Snakeblenny (56)<br>Fourspot flounder (56)<br>Fourbeard rockling (44)<br>Haddock (44)<br>White hake (44)<br>Alewife (33)<br>Goosefish (33)   | Sea raven (60)<br>Thorny skate (54)<br>Atlantic herring (54)<br>Goosefish (54)<br>Fourbeard rockling (38)<br>Butterfish (38)<br>Haddock (38)<br>Redfish (38)<br>Cunner (38)   |
| Infrequent | American sandlance (11)<br>Pollock (11)<br>Atlantic herring (11)<br>Redfish (11)<br>Winter skate (11)   | Alligatorfish (31)<br>Snakeblenny (31)<br>Yellowtail flounder (31)<br>Wrymouth (23)<br>Winter flounder (23)<br>Mailed sculpin (23)<br>Daubed shanny (23)<br>Blueback herrring (15)<br>Atlantic mackeral (15)<br>Fourspot flounder (15)<br>American shad (15)<br>Pollock (15)<br>Windowpane (8)<br>Cusk (8)<br>Scup (8)<br>Spiny dogfish (8) |

a. species and frequency of occurrence (%)

common: present in > 2/3 of trawls

occasional: present in 1/3 to 2/3 of trawls

infrequent: present in < 1/3 of trawls

spring trawls: n = 9; fall trawls n = 13

NMFS trawls: n = 8; MDMF trawls: n = 14

TABLE 3.C.2-5: Summary of winter National Marine Fisheries Survey  
bottom trawls in the vicinity of the MBDS (1979-1984).<sup>a,b</sup>

| Species                    | Winter        |               |
|----------------------------|---------------|---------------|
|                            | Number<br>(%) | Weight<br>(%) |
| American plaice            | 66            | 45            |
| Winter flounder            | 5             | 13            |
| Pollock                    | 8             | 3             |
| Witch flounder             | 2             | 5             |
| Atlantic cod               | <1            | 8             |
| Silver hake                | 6             | <1            |
| Ocean pout                 | 1             | 6             |
| Atlantic herring           | 5             | 1             |
| Alewife                    | <1            | 5             |
| Redfish                    | 1             | 3             |
| Sea raven                  | <1            | 3             |
| Other Species <sup>c</sup> | 7             | 8             |

| Summary Statistics:                   | Winter |
|---------------------------------------|--------|
| mean weight (kg) of fish caught/rawl: | 101    |
| mean number of fish caught/rawl:      | 630    |
| mean number of species caught/rawl:   | 13     |
| total number of species caught:       | 19     |
| number of trawls:                     | 3      |
| mean water depth (m):                 | 82     |

- a. summary including all species and catch data from individual trawls is presented in the Appendix.
- b. expressed as a percentage of total catch.
- c. species comprising less than 3 % of total catch (number and weight) in both NMFS and MDMF surveys.

TABLE 3.C.2-6: Summary of spring National Marine Fisheries Survey and Massachusetts Division of Marine Fisheries bottom trawls in the vicinity of MBDS (1979 - 1984).<sup>a,b</sup>

| Species                                | MDMF Trawls |            | NMFS Trawls |            |
|--|-------------|------------|-------------|------------|
|  | Number (%)  | Weight (%) | Number (%)  | Weight (%) |
| American plaice                        | 81          | 59         | 67          | 42         |
| Ocean pout                             | 5           | 20         | 3           | 3          |
| Atlantic cod                           | 1           | 6          | 1           | 21         |
| Witch flounder                         | <1          | 4          | 14          | 13         |
| Thorny skate                           | <1          | <1         | 3           | 9          |
| American sandlance                     | 0           | 0          | 5           | <1         |
| Snakebleny                             | 3           | 1          | 0           | 0          |
| Winter skate                           |             |            | <1          | 4          |
| Other Species <sup>c</sup>             | 10          | 10         | 9           | 8          |
| -----                                  |             |            |             |            |
| Summary Statistics:                    | MDMF        |            | NMFS        |            |
| mean weight (kg) of fish caught/trawl: | 165         |            | 130         |            |
| mean number of fish caught/trawl:      | 1360        |            | 411         |            |
| mean number of species caught/trawl:   | 17          |            | 12          |            |
| total number of species caught:        | 24          |            | 18          |            |
| number of trawls:                      | 6           |            | 3           |            |
| mean water depth (m):                  | 73          |            | 78          |            |
| -----                                  |             |            |             |            |

- summary including all species and catch data from individual trawls is presented in the Appendix.
- expressed as a percentage of total catch by NMFS or MDMF trawls.
- species comprising less than 3 % of total catch (number and weight) in both NMFS and MDMF surveys.

TABLE 3.C.2-7: Summary of summer National Marine Fisheries Survey  
bottom trawls in the vicinity of the MBDS (1979-1984)<sup>a,b</sup>

| Species                    | Summer        |               |
|----------------------------|---------------|---------------|
|                            | Number<br>(%) | Weight<br>(%) |
| American plaice            | 80            | 32            |
| Thorny skate               | 2             | 21            |
| Witch flounder             | 7             | 17            |
| Spiny dogfish              | 1             | 9             |
| Atlantic cod               | 2             | 7             |
| Red hake                   | 3             | 6             |
| Fourspot flounder          | 1             | 4             |
| Other Species <sup>c</sup> | 4             | 4             |

Summary Statistics:

|                                   |     |
|-----------------------------------|-----|
| weight (kg) of fish caught/trawl: | 114 |
| number of fish caught/trawl:      | 349 |
| number of species caught/trawl:   | 14  |
| number of trawls:                 | 1   |
| water depth (m):                  | 72  |

a. data for all species is presented in the Appendix

b. expressed as a percentage of total catch.

c. species comprising less than 3 % of total catch (number and weight) in both NMFS and MDMF surveys.

TABLE 3.C.2-8: Summary of fall National Marine Fisheries Survey and Massachusetts Division of Marine Fisheries bottom trawls in the vicinity of MBDS (1979 - 1984).<sup>a,b</sup>

| Species                                | MDMF Trawls |            | NMFS Trawls |            |
|--|-------------|------------|-------------|------------|
|  | Number (%)  | Weight (%) | Number (%)  | Weight (%) |
| American Plaice                        | 59          | 32         | 29          | 13         |
| Silver Hake                            | 16          | 12         | 18          | 7          |
| Red Hake                               | 8           | 27         | 4           | 7          |
| Alewife                                | 1           | <1         | 23          | 15         |
| Atlantic Cod                           | 1           | 1          | 9           | 28         |
| Witch Flounder                         | 2           | 8          | 1           | 3          |
| Ocean Pout                             | 2           | 5          | 3           | 3          |
| Golden Redfish                         | <1          | <1         | 5           | 5          |
| Goosefish                              | <1          | 4          | <1          | 5          |
| Thorny Skate                           | <1          | 1          | 1           | 6          |
| Atlantic Herring                       | 5           | 2          | <1          | <1         |
| Snakebleny                             | 3           | 3          |             |            |
| Other Species <sup>c</sup>             | 3           | 5          | 7           | 8          |
| Summary Statistics:                    |             |            |             |            |
|  | MDMF        |            | NMFS        |            |
| mean weight (kg) of fish caught/trawl: | 114         |            | 138         |            |
| mean number of fish caught/trawl:      | 861         |            | 393         |            |
| mean number of speeis caught/trawl:    | 15          |            | 15          |            |
| total number of species caught:        | 29          |            | 25          |            |
| number of trawls:                      | 8           |            | 5           |            |
| mean water depth (mm):                 | 71          |            | 72          |            |

a. summary including all species and catch data from individual trawls is presented in the Appendix.

b. expressed as a percentage of total catch by NMFS or MDMF trawls.

c. species comprising less than 3 % of total catch (number and weight) in both NMFS and MDMF surveys.

Table 3.C.2-9: Results of gill net deployments within MBDS in June of 1985.

| Species          | Mean Catch (number of fish) <sup>a</sup> |                         |
|------------------|--|-------------------------|
|                  | Dredged Material<br>(n=2)                | Natural Bottom<br>(n=4) |
| Spiny dogfish    | 8  | 15                      |
| Redfish          | 2  | <1                      |
| Silver hake      | <1                                       | <1                      |
| Alewife          | <1                                       |                         |
| Longhorn sculpin |  | <1                      |

a. 6 hour deployment (1000-1600 hr) on June 6 or June 7)

Table 3.C.2-10: Submersible observations of fish communities at the Massachusetts Bay Disposal Site (June 8, 1985)<sup>a</sup>

| Taxa                           | Fish Observed (per m <sup>2</sup> ) in Various Habitats |               |               |             |
|--------------------------------|---|---------------|---------------|-------------|
|                                | Dredged Material  | Mud/Clay (SE) | Mud/Clay (NE) | Cobble (NE) |
| Snakeblenny                    | 0.02  | 0.09          | 0.28          | 0.02        |
| Ocean pout                     | 0.02  | 0.02          | 0.02          | 0.06        |
| unidentified sculpin           |   | <0.01         | 0.02          | 0.04        |
| unidentified flounder          |   |               | 0.09          | 0.01        |
| Spiny dogfish                  |   | 0.01          |               | 0.01        |
| unidentified skate             |   |               |               | 0.01        |
| Sandlance larvae               |   | 0.20          | 0.01          |             |
| unidentified larvae            |   | 0.02          |               |             |
| Total (fish/m <sup>2</sup> )   | 0.04  | 0.33          | 0.42          | 0.15        |
| Area sampled (m <sup>2</sup> ) | 44  | 388           | 189           | 247         |

a. based on slow replay analysis of video tape footage.



Table 3.C.2-11: Fish captured by gill nets deployed on dredged material at MBDS in October of 1985.<sup>a</sup>

| Species            | Total Catch |             |            |            |
|--------------------|-------------|-------------|------------|------------|
|                    | Number      | Weight (kg) | Number (%) | Weight (%) |
| Redfish            | 90          | 46.5        | 44         | 33         |
| Silver hake        | 44          | 15.3        | 22         | 11         |
| Red hake           | 26          | 25.6        | 13         | 18         |
| Thorny skate       | 3           | 26.0        | 1          | 19         |
| Atlantic cod       | 12          | 16.2        | 6          | 12         |
| Atlantic mackerel  | 11          | 5.3         | 5          | 4          |
| Atlantic herring   | 13          | 3.8         | 6          | 3          |
| American plaice    | 3           | 0.7         | 1          | 1          |
| Fourbeard rockling | 2           | 0.2         | 1          | <1         |
| Total:             | 204         | 139.6       | -          | -          |

a. fish caught by two attached pannels (total area: 166 m<sup>2</sup>)  
 deployed from 1200 October 7 until 1130 October 8.

TABLE 3.C.2-12: Summary of COE bottom trawls in the vicinity of MBDS.

| Species             | October 1985               |                              |                            | February 1986                |                            |                              |
|---------------------|----------------------------|------------------------------|----------------------------|------------------------------|----------------------------|------------------------------|
|                     | Reference Area             |                              | MBDS <sup>a</sup>          | MBDS                         |                            |                              |
|                     | Number <sup>b</sup><br>(%) | Weight <sup>b,c</sup><br>(%) | Number <sup>b</sup><br>(%) | Weight <sup>b,c</sup><br>(%) | Number <sup>b</sup><br>(%) | Weight <sup>b,c</sup><br>(%) |
| American plaice     | 34                         | 23                           | 39                         | 28                           | 54                         | 19                           |
| Witch flounder      | 15                         | 19                           | 28                         | 20                           | 6                          | 13                           |
| Silver hake         | 30                         | 15                           | 14                         | 7                            | 11                         | 1                            |
| Red hake            | 10                         | 28                           | 5                          | 11                           |                            |                              |
| Redfish             | 5                          | 4                            | 10                         | 15                           | 9                          | 21                           |
| Cusk                |                            |                              |                            |                              | 18                         | 16                           |
| Ocean pout          | <1                         | <1                           |                            |                              | 5                          | 24                           |
| Thorny skate        | 1                          | 6                            | <1                         | 9                            |                            |                              |
| White hake          | 2                          | 2                            | 1                          | 5                            |                            |                              |
| Fourbeard rockling  | 1                          | <1                           | 1                          | <1                           | 7                          | 3                            |
| Atlantic cod        | 1                          | 1                            | <1                         | 1                            |                            |                              |
| Goosefish           |                            |                              | <1                         | 4                            |                            |                              |
| Wrymouth            | <1                         | <1                           |                            |                              | <1                         | 2                            |
| Longhorn sculpin    | <1                         | <1                           |                            |                              | 2                          | <1                           |
| Yellowtail flounder |                            |                              |                            |                              |                            |                              |
| Clearnose skate     |                            |                              | <1                         | <1                           |                            |                              |
| Sea robin           |                            |                              | <1                         | <1                           |                            |                              |
| Windowpane          |                            |                              |                            |                              | <1                         | <1                           |
| Alligatorfish       |                            |                              |                            | <1                           | <1                         | <1                           |
| Pipefish            |                            |                              |                            |                              | <1                         | <1                           |
| Winter flounder     |                            |                              |                            |                              | <1                         | <1                           |

Summary Statistics<sup>d</sup>

|  | October 1985 | February 1986 |
|--|--------------|---------------|
| Reference Area                         | MBDS         | MBDS          |
| mean number of fish caught/trawl:      | 213 (16)     | 207 (2)       |
| mean weight (kg) of fish caught/trawl: | 109 (10)     | 74 (9)        |
| mean number of speceis caught/trawl:   | 10           | 11            |
| total number of speceis caught:        | 12           | 13            |
| number of trawls:                      | 2            | 2             |

a. area trawled included both natural bottom and dredged material within MBDS

b. expressed as a percentage of total catch.

c. because of missing data, some weights were estimated using length measurements and published length-weight relationships (Bigelow and Schroeder 1953; Clayton et al. 1978).

d. mean and standard deviation

Table 3.C.2-13: Average commercial fisheries catch in the vicinity of the Massachusetts Bay Disposal Site (1982-1984).<sup>a</sup>

| Species             | Commercial landings |            |
|---------------------|---------------------|------------|
|                     | 1000's of kg        | % of total |
| Atlantic cod        | 1861                | 29         |
| American plaice     | 1036                | 16         |
| Winter flounder     | 692                 | 11         |
| Yellowtail flounder | 636                 | 10         |
| Haddock             | 428                 | 7          |
| Witch flounder      | 406                 | 6          |
| Silver hake         | 312                 | 5          |
| Pollock             | 304                 | 5          |
| Menhaden            | 184                 | 3          |
| Herring             | 174                 | 3          |
| Spiny dogfish       | 95                  | 2          |
| Shrimp              | 85                  | 1          |
| Wolfish             | 42                  | 1          |
| Red hake            | 39                  | 1          |
| Lobster             | 17                  | <1         |
| Summer flounder     | 5                   | <1         |
| Total:              | 6316                |            |

a. catch from 10' square centered at  
Longitude: 40.25'; Latitude: 70.35'

Table 3.C.2-14: Life history information of fish which may spawn in the vicinity of MBDS.<sup>a</sup>

| Species             | Principle Spawning Months | Spawning Habitat <sup>b</sup> | Substrate/ Depth Preference <sup>c</sup> | Incubation Period | Larval Habitat (and length of larval period) <sup>d</sup> |
|---------------------|---------------------------|-------------------------------|--|-------------------|---|
|                     | N D J F M A M J J A S O   |                               |  |                   |   |
| Pollock             | N D J                     | P                             | 27-91 m                                  | 9 d               | P (2 m)   |
| Longhorn sculpin    | N D J F                   | D                             | HS: < 91 m                               | < 3 m             | P (1 m) then D  |
| Atlantic wolffish   | N D J F                   | D                             | HS                                       |                   | D   |
| Rock gunnel         | N D J F M                 | D                             | peb., grav., stone                       |                   | P   |
| Snakeblenny         | D J F                     | D                             | U: < 91 m                                |                   | P   |
| Wrymouth            | D J F                     | D                             | U  |                   | P   |
| Atlantic cod        | D J F M A                 | P                             | prin. < 64 m                             | 14-30 d           | P (2 m)   |
| American sandlance  | J F M A                   | D                             | sand, gravel                             | 2 m               | P (2-3 m) then D  |
| Haddock             | F M A M                   | P                             | prin. 27-183 m                           | 9-23 d            | P (NS 6 w)  |
| American plaice     | F M A M J                 | P                             | prin. < 90 m                             | 11-14 d           | P (3-4 m)   |
| White hake          | F M A M J J               | P                             |  |                   | P   |
| Atlantic mackerel   | A M J J                   | P                             |  | 2-6 d             | P (2 m)   |
| Cusk                | A M J J A                 | P                             |  | 5 d               | P   |
| Yellowtail flounder | M A M J J A               | P                             | 35-90 m                                  | 7-8 d             | P (4-6 m)   |
| Witch flounder      | A M J J A                 | P                             | HB                                       |                   | P   |
| Radiated shanny     | M J J A                   | D                             | prin. 35-80 m                            |                   | P (NS then NB)  |
| Pourspot flounder   | M J J                     | P                             |  | < 2 d             | P   |
| Redfish             | M J J A                   | P                             |  | 7-22 d            | P   |
| Atlantic menhaden   | J J A S                   | P                             |  |                   | P (3 m) then D  |
| Goosefish           | J J A S                   | P                             |  | 2-4 d             | P then D  |
| Fourbeard rockling  | M J J A S O               | P                             |  | 2 d (?)           | P (2-3 m) then D  |
| Red hake            | M J J A S O               | P                             |  | 2.5-3.5 m         | P   |
| Silver hake         | J J A S O                 | P                             | rock; prin. < 50 m                       | 11-40 d           | P (5-8 m NS)  |
| Ocean pout          | S O                       | D                             | rock, grav.: 4-55 m;                     | up to 3 m         | P   |
| Atlantic herring    | S O                       | D                             | U, Sponges                               |                   |   |
| Sea Raven           | N D                       | D                             |  |                   |   |
| Alligatorfish       | N D                       | D                             |  |                   |   |

a. Bigelow and Schroeder (1953); Clayton et al. (1978); Grosslein and Azarovitz (1982); Shetling et al (1980); TRIGOM (1974)

b. D: demersal; P: pelagic

c. based on known spawning habits or adult distribution;

U: unconsolidated substrate; HS: hard substrate; AB: aquatic bed

d. NS: near surface; NB: near bottom

e. ovoviparous

Table 3.C.2-15: Occurrence and abundance of fish eggs at Seabrook,<sup>a</sup>  
New Hampshire.

| Season/Species Assemblage <sup>b</sup>  | Mean abundance<br>(eggs/1000 m <sup>2</sup> ) |
|---|---|
| -----                                   |   |
| Fall-Winter (Nov-Feb)                   |   |
| Atlantic cod/Haddock                    | 130   |
| Pollock                                 | 90  |
| Winter-Spring (Jan-April)               |   |
| American plaice                         | 129   |
| Atlantic cod/Haddock <sup>c</sup>       | 78  |
| Spring (April-May)                      |   |
| American plaice                         | 995   |
| Cunner/Yellowtail flounder <sup>d</sup> | 407   |
| Cod/Haddock                             | 239   |
| Fourbeard rockling                      | 148   |
| Spring (May-June)                       |   |
| Cunner/Yellowtail flounder              | 14029   |
| Mackerel                                | 7083  |
| Fourbeard rockling                      | 923   |
| American plaice                         | 402   |
| Summer (June-August)                    |   |
| Cunner/Yellowtail flounder <sup>e</sup> | 22646   |
| Hake                                    | 7281  |
| Mackerel                                | 6362  |
| Fourbeard rockling/Hake                 | 2422  |
| Summer (July-Sept)                      |   |
| Hake                                    | 6471  |
| Cunner/Yellowtail flounder              | 6426  |
| Windowpane flounder                     | 290   |
| Fourbeard rockling                      | 143   |
| Fall (Sept-Oct)                         |   |
| Hake                                    | 477   |
| Silver hake                             | 109   |
| Fourbeard rockling/hake                 | 108   |
| Fourbeard rockling                      | 81  |
| -----                                   |   |

a. adapted from Normandeau (1985); assemblages delineated by numerical classification of nearshore samples collected during 1975-1984.

b. principal months in which assemblage occurred and dominant species

c. predominately cod

d. predominately yellowtail flounder

e. predominately cunner

Table 3.C.2-16: Occurrence and abundance of fish larvae  
at Seabrook, New Hampshire.<sup>a</sup>

| Season/Species Assemblage <sup>b</sup> | Mean abundance<br>(larvae/1000 m <sup>2</sup> ) |
|--|---|
| Fall-Winter (Oct-Nov)                  |   |
| Atlantic herring                       | 457   |
| Fall-Winter (Nov-Dec)                  |   |
| Atlantic herring                       | 49  |
| Pollock                                | 42  |
| Winter-Spring (Dec-Feb))               |   |
| American sand lance                    | 398   |
| Pollock                                | 63  |
| Winter-Spring (Feb-April)              |   |
| American sandlance                     | 1004  |
| Rock gunnel                            | 207   |
| Spring (May-June)                      |   |
| Winter flounder                        | 217   |
| American plaice                        | 179   |
| Seasnails                              | 129   |
| Summer (July-Aug)                      |   |
| mackerel                               | 2280  |
| Cunner                                 | 1993  |
| Summer-Fall (Aug-Oct)                  |   |
| Fourbeard rockling                     | 35  |
| Hake (Urophycis spp.)                  | 11  |

- a. adapted from Normandeau (1985); principle assemblages deliniated by numerical classification of nearshore samples collected during 1975-1984.
- b. principal months in which assemblages occured and dominant species.

Table 3.C.2-17: Occurrence and abundance of larval fish in Massachusetts Bay.<sup>a</sup>

| Species                        | Occurrence and Abundance. <sup>b</sup> |    |    |   |    |    |   |   |   |    |    |    |
|--------------------------------|--|----|----|---|----|----|---|---|---|----|----|----|
|                                | J                                      | F  | M  | A | M  | J  | J | A | S | O  | N  | D  |
| Pollock                        |  |    |    |   |    |    |   |   |   |    |    |    |
| American sandlance             | H                                      | M  | M  | M | M  | M  |   |   | L | L  | M  | M  |
| American plaice                | VH                                     | VH | VH | M | M  | M  |   |   |   |    |    | VH |
| Haddock                        |  |    |    | H | H  | M  |   |   |   |    |    |    |
| Atlantic mackerel              |  |    |    |   | L  | M  | M |   |   |    |    |    |
| Redfish                        |  |    |    |   | VH | VH | H | M |   |    |    |    |
| Atlantic cod                   |  |    |    |   | L  | L  | M | M |   |    |    |    |
| Yellowtail flounder            |  |    |    |   | M  | H  | H | M |   |    | L  | L  |
| Windrowpane                    |  |    |    |   | M  | M  | M | M |   |    |    |    |
| Witch flounder                 |  |    |    |   | L  | L  | M | M |   |    |    |    |
| Cunner                         |  |    |    |   | L  | M  | H | H | M | M  | L  | L  |
| Hakes ( <i>Urophycis</i> spp.) |  |    |    |   |    |    | H | H | M | M  | L  | L  |
| Silver hake                    |  |    |    |   |    |    | M | H | M | H  | M  | M  |
| Atlantic herring               |  |    |    |   | M  | M  | M | L |   | VH | VH | VH |

a. based on offshore 1977-1984 MARMAP surveys2(Morse et al. 1987)

b. maximum reported concentrations (per 100 m ): VH: 1001-10000;  
H: 101-1000; M: 11-100; L: 1-10

Table 3.2.C.18: Feeding guilds of fish likely to occur in the vicinity of the Foul Area Disposal Site<sup>a</sup>

| Planktonic         | Demersal/Semidemersal |
|--------------------|-----------------------|
| Atlantic menhaden  | Fourbeard Rockling    |
| Alewife            | Longhorn sculpin      |
| Blueback herring   | Snakeblenny           |
| American shad      | Barndoor skate        |
| American sandlance | Little skate          |
| Atlantic herring   | Winter skate          |
|                    | Thorny skate          |
| Necktonic          | Cusk                  |
|                    | Sea raven             |
| Alligator fish     | Wrymouth              |
| Redfish            | Winter flounder       |
| Pollock            | Fourspot flounder     |
| White hake         | Windowpane            |
| American pollock   | American plaice       |
| Silver hake        | Witch flounder        |
| Bluefish           | Yellowtail flounder   |
| Spiny dogfish      | Scup                  |
| Atlantic mackerel  | Northern searobin     |
| Red hake           | Goosefish             |
|                    | Rock gunnel           |
| Necktonic/Demersal | Haddock               |
| Cunner             | Ocean Pout            |
| Atlantic cod       | Atlantic wolffish     |

a. Bigelow and Schroeder 1953; Clayton et al. 1978; Grosslein and Azarovitz 1982; Michaels and Bowman 1983; Sheting et al. 1980; TRIGOM 1974



Table 3.C.2-19: Stomach Contents (%) Of Fish Caught At FADS, September 1985,  
Based On Number Of Food Items

| Fish Species<br>Capture Method | Atlantic Cod<br>Trawl | American Plaice<br>Trawl | Witch<br>Flounder<br>Trawl | Winter<br>Flounder<br>Hets |
|--------------------------------|-----------------------|--------------------------|----------------------------|----------------------------|
| No. Examined                   | 12                    | 20                       | 12                         | 9                          |
| No. with food                  | 8                     | 12                       | 10                         | 5                          |
| No. food items                 | 45                    | 51                       | 329                        | 547                        |
| RHYNCHOCOELA                   | -                     | -                        | -                          | 1.3                        |
| SIPUNCULA                      | -                     | -                        | -                          | 0.9                        |
| ANNELIDA<br>Polychaeta         | 17                    | -                        | 89.9                       | 51.4                       |
| MOLLUSCA<br>Bivalvia           | -                     | 16.6                     | 4.1                        | -                          |
| ARTHROPODA<br>Crustacea        | 57.4                  | -                        | 1.3                        | 41.8                       |
| Amphipoda                      | 2.1                   | -                        | -                          | -                          |
| Mysidacea                      | 4.2                   | -                        | -                          | -                          |
| Euphausiacea                   | 10.6                  | 7.3                      | 0.9                        | -                          |
| Caridea                        | -                     | -                        | -                          | 0.18                       |
| Tanidacea                      | -                     | -                        | 3.6                        | -                          |
| Cumacea                        | -                     | -                        | -                          | -                          |
| ECHINODERMATA                  | 4.2                   | 75.9                     | -                          | 0.7                        |
| CHORDATA<br>Ascidiacea         | -                     | -                        | -                          | 0.5                        |
| OTHER                          | 4.5                   | 0.2                      | 0.2                        | 3.22                       |

Table 3.C.2-20: Feeding strategy groups at the MBDS

|             |   | Group | Species  | Size Class  | Number of<br>Individuals              |
|-------------|---|-------|--|---|---------------------------------------|
| Group I -   | Fishes feeding on prey less than or equal to 1.00 mm or smaller with a modal prey size around 0.5mm.  | I     | American plaice<br>American plaice<br>witch flounder<br>witch flounder   | 10-14.9 cm<br>30 + cm<br>10-14.9 cm<br>10-14.9 cm                                     | 11<br>1<br>3<br>1                     |
| Group II -  | Fishes that exploit a range of prey sizes and that are not clearly small prey or large prey exploiters. Group II contains four sub-groups:  | IIa   | witch flounder<br>witch flounder   | 15-19.9 cm<br>15-19.9 cm  | 6<br>5                                |
|             | a) fishes that exploit prey between greater than or equal .063mm and less than or equal to 2.00mm. No prey size mode is apparent.   | IIb   | American plaice<br>American plaice<br>witch flounder<br>witch flounder<br>witch flounder<br>yellowtail fl.                       | 15-19.9 cm<br>15-19.9 cm<br>25-29.9 cm<br>20-24.9 cm<br>20-24.9 cm<br>25-29.9 cm      | 20<br>20<br>20<br>3<br>7<br>1         |
|             | b) fishes that exploit prey between .250 and 3.35mm. The modal prey size exploitation is between 1.00 and 2.00mm.   | IIc   | American plaice<br>witch flounder  | 10-14.9 cm<br>15-19.9 cm  | 20<br>5                               |
|             | c) fishes that exploit a range of prey sizes between greater than or equal to .063mm and 6.35mm.  | IId   | witch flounder<br>witch flounder<br>witch flounder   | 30 + cm<br>20-24.9 cm<br>25-29.9 cm   | 20<br>5<br>6                          |
|             | d) fishes whose exploitation is uniformly within the range between greater than or equal to 1.00 and 6.35mm.  | III   | American plaice<br>American plaice<br>American plaice<br>American plaice<br>American plaice<br>American plaice<br>witch flounder | 20-24.9 cm<br>20-24.9 cm<br>25-29.9 cm<br>25-29.9 cm<br>30 + cm<br>30 + cm<br>30 + cm | 20<br>20<br>16<br>20<br>6<br>13<br>20 |
| Group III - | Fishes that do not exploit small or medium sized prey. Exploitation is overwhelmingly among prey that are greater than or equal to 3.35mm. A very pronounced peak is evident in the greater than or equal to 6.35mm category. |       |  |   |                                       |

Table 3.0.2-2: Feeding efficiency of Witch flounder and American plaice at MBDS as indicated by weight of stomach contents.

| <u>Species</u>  | <u>Size Class</u> | <u>Mean Weight Of Food Per Stomach<br/>(in grams)</u> |                      |
|-----------------|-------------------|---|----------------------|
|                 |                   | <u>MBDS (n)</u>                                       | <u>Reference (n)</u> |
| witch flounder  | 10-14.9 cm        | .02 (3)   | .17 (1) *            |
|                 | 15-19.9 cm        | .17 (T-1) ** (6)<br>.24 (T-2) (5)                     | .16 (5)              |
|                 | 20-24.9 cm        | .49 (T-1) (7)<br>.19 (T-2) (3)                        | .23 (6)              |
|                 | 25-29.9 cm        | .50 (20)  | .18 (5)              |
|                 | 30+ cm            | .60 (20)  | .55 (20)             |
| American plaice | 10-14.9 cm        | .01 (11)  | .01 (20)             |
|                 | 15-19.9 cm        | .07 (20)  | .04 (20)             |
|                 | 20-24.9 cm        | .13 (20)  | .06 (20)             |
|                 | 25-29.9 cm        | .65 (16)  | .31 (20)             |
|                 | 30+ cm            | .04 (T-1) (1)<br>.91 (T-2) (6)                        | 1.31 (13)            |

\* Questionable value due to sample size.

\*\* Refers to trawl number.

Table 3.C.2-22: Invertebrates captured in NMFS and MDMF bottom trawls in the vicinity of MBDS (1979- 1984).

| Species           | Mean number caught/trawl |        |      |        |        |      |  |
|-------------------|--------------------------|--------|------|--------|--------|------|--|
|                   | NMFS                     |        |      | MDMF   |        |      |  |
|                   | Spring                   | Summer | Fall | Winter | Spring | Fall |  |
| Shortfin squid    |                          | 39     | 20   |        |        | 22   |  |
| Longfin squid     |                          |        | 26   |        |        | 11   |  |
| Shrimp            |                          |        |      |        | P      | P    |  |
| Lobster           | 7                        |        | 6    | 5      | 4      | <1   |  |
| Rock Crab         |                          |        | <1   |        | <1     | 2    |  |
| Jonah crab        |                          | 1      |      |        |        | <1   |  |
| Sea scallops      | 4                        |        |      |        | 2      | <1   |  |
| Octopus           |                          |        |      |        |        |      |  |
| Number of trawls: | 4                        | 1      | 5    | 3      | 6      | 8    |  |

Table 3.C.2-23: Life history characteristics of commercially important invertebrates present at MBDS.<sup>a</sup>

| Species   | Habitat Preference  | Seasonality  | Reproduction   |
|---|---|--|--|
| American lobster<br>( <u>Homarus americanus</u> )     | depth: 0-700 m. prefers irregular bottom, but freq. occur on mud or sand            | moves nearshore during spring and summer. prob. absent from FADS June - September                  | mating occurs May - July. eggs held by female until following summer. larvae pelagic for 3 - 6 weeks                         |
| Rock crab<br>( <u>Cancer irroratus</u> )              | depth: 0-600 m. sand or mud, sometimes gravel                                       | young move inshore fall, winter, and spring  | mating occurs late fall - early winter (Maine). eggs held by female until June - Aug. larvae pelagic 1.5 - 2 m.              |
| Jonah crab<br>( <u>C. borealis</u> )                  | depth: 0-800 m. prefers rocky bottom  | small - medium sized individuals found nearshore seasonally  | mating season June - Dec. larvae pelagic, late spring - summer   |
| Red crab<br>breeding<br>( <u>Geryon quinquedens</u> ) | depth: prin. 320 - 640 m. prefers silty clay, found on both hard and soft bottom    |  | mating occurs September - early summer. eggs held by female until hatching (April-June). larvae pelagic for prolonged period |
| Northern shrimp<br>( <u>Pandalus borealis</u> )       | depth: 9 - 329 m. prin. 100 - 250 m. prefer unconsolidated bottom (mud, sand, silt) | adults move inshore during winter  | mating occurs August - Sept. eggs held by female until hatching (Feb. - April). larvae pelagic for ca. 2 months (inshore)    |
| Short-fin squid<br>( <u>Illex illecebrosus</u> )      | pelagic   | migratory between coastal and offshore. prob. most common at FADS from summer through early autumn | spawning occurs prin. offshore on coastal shelf  |
| Long-fin squid<br>( <u>Loligo pealei</u> )            | pelagic   | same as short-fin squid  | spawning occurs April - Sept. eggs demersal in clusters at 3 - 30 m  |
| Sea scallops<br>( <u>Placopecten magellanicus</u> )   | depth: 0-200 m. prin. 40-100 m sand or silty sand                                   | no directed movements or seasonal migrations   | spawning Sept. - Oct. larval period 35 days  |
| Ocean quahog<br>( <u>Arctica islandica</u> )          | depth: prin. 11 - 250 m. most abundant on soft sandy mud or silty sand              | no directed movements or seasonal migrations   | spawning occurs late June - early Oct. (peak August) 60 day larval period  |

a. Fefer and Schettig 1980; Grosslein and Azarovitz 1982; Morse et al. 1987; TRIGOM 1974; Williams 1984

### 3.C.3. BENTHOS

There have been relatively few studies of the benthic fauna of Massachusetts Bay and Stellwagen Basin area. In 1976, an extensive survey of the benthic community of Massachusetts Bay was conducted by the New England Aquarium for the Massachusetts Division of Water Pollution Control (Gilbert et. al. 1976). Seventy-three samples were taken from Massachusetts Bay. The results of this study indicated that the benthic community is dominated by spionid polychaetes such as Spio (limicola) and to a lesser extent Prionospio (steenstrupi). Gilbert called the area a Spio (limicola) - Thyasira (gouldi) community.

Benthic data were collected from various locations in Cape Cod Bay as part of the Environmental Impact Report for the identification of dredged disposal sites in Cape Cod Bay. The results of this survey showed that the area is dominated by Spio limicola and Mediomastus californiensis. Together, these two species made up 40 to 50% of the individuals. Secondary species which were abundant included Euchone incolor, Cossura longocirrata, and oligochaetes.

These studies indicate a pattern in which Massachusetts Bay sediments are dominated by spionid assemblages.

A description of the benthic community near the present day Massachusetts Bay was provided by Gilbert (1975). Five stations and a control were sampled in April, May, June and July. These stations are adjacent to MBDS in an area historically used for chemical disposal. Two of the stations are located within the boundaries of the dredge material disposal site. In general species composition and abundances among the 6 sites were similar. These areas were dominated by Spio limicola and Heteromastus filiformis.

Five stations from Gilberts 1976 survey were located on the perimeter of the Massachusetts Bay (See Table 3.C.3-2 for locations). These areas were dominated by Spio limicola, Prionospio steenstrupi, Ampharete acutifrons and Heteromastus filiformis.

Several cruises between 1979 and 1982 in Massachusetts Bay by the National Marine Fisheries Service as part of the Northeast Monitoring Program have resulted in the collection of a large benthic data set for Massachusetts Bay. The station nearest the Massachusetts Bay Disposal Site (42°19.0 N, 70°36.0 W) showed an area dominated by Spio (limicola) and to a lesser extent Prionospio steenstrupi and Anobothrus gracilis (Fig. 3.C.3-1 and 3.C.3-2).

The pattern that emerges from these studies is that the benthic community in the general vicinity of the Massachusetts Bay Disposal Site does not appear to be substantially different from the Massachusetts Bay system.

An analysis of the benthic community in the Massachusetts Bay Disposal Site was undertaken to evaluate the impact of disposal operations. The benthic analysis and sampling design were facilitated through the use of REMOTS reconnaissance. A 0.1m<sup>2</sup> Smith-McIntyre grab, sieved through a 0.5mm screen, was used for all NED samples. Comparisons were made between smaller (and larger) mesh sieves and the 0.5 mm was determined the most cost efficient in terms of data versus cost. The REMOTS survey revealed two major grain size facies at MBDS (silt-clay and coarse sand) and three types of biological community. Benthic stations were located to document: 1) the benthic community in fine-grained sediments ; 2) the benthic community on fine-grained sediments affected by dredged material within the designated MBDS boundary and 3) the dense tubicolous polychaete assemblage consisting mainly of suspension and surface deposit-feeding fauna located on the coarse sand/cobble bottom within the designated MBDS boundary. Five benthic stations were established near the Massachusetts Bay Disposal Site. This includes a mud and a sand station within the Massachusetts Bay Disposal Site (Mud Station Off Dredged Material and Sand Station), and a mud and sand reference station outside of MBDS (Mud Reference Station and Sand Reference Station). In addition a station was located on dredged material in the site (Mud Station On Dredged Material). The results of this analysis are summarized in Figures 3.C.3-2 through 3.2.C.3-5. The raw data are presented in the SAIC, 1987 Volume II.

The mud reference station was located just outside the Massachusetts Bay to the southeast (42°24.686', 70°32.814') in an area of silt-clay 500 meters southeast of the boundary. The REMOTS photographs indicated that this area was characterized by so called "conveyor-belt" type deposit feeding organisms, which feed on subsurface sediments in a head down orientation and defecate at the sediment surface. Feeding voids and distinct granulometric changes in sediment particles at the surface are indicative of this type of community. This station was chosen to serve as a control station for comparison with the silt-clay stations within MBDS (Mud Station On Dredged Material = MBDS-ON and Mud Station Off Dredged Material = MBDS-OFF).

The Mud Reference Station was sampled in June and September 1985 and in January 1986. The Mud Station Off Dredged Material within the disposal site (42°24.956', 70° 33.919') was sampled in September 1985. Side-scan sonar, submersible observations and REMOTS photographs all showed a generally flat and uniform bottom at both of these stations. The number of species in the 12 mud station replicates varied over time from 33 to 49. The Mud Reference Station was dominated by annelids (polychaetes and oligochaetes). The other taxa making up less than 10% of the samples. The most abundant species was the polychaete Paraonis gracilis. This small deposit feeding polychaete (Family: Paraonidae) dominated at this station over all seasons, making up 20 to 38% of the individuals. Motile epifauna, tubicolous polychaetes and amphipods, and heavy shelled bivalves were absent or occurred at reduced densities at MBDS-ON. Other taxa which were associated with silt-clay sediments were the bivalve, Yoldia thraciacaeformis and the holothurian, Molpadia oolitica. Rhyncocoels were found in all substrate types but were the most abundant in mud samples.

The Mud Station Off Dredged Material was similar in species composition to the Mud Reference station. Paraonis gracilis, was again the dominant species at this station. The most obvious difference in the species composition between Mud Off station and the Mud Reference station was the increased abundance of oligochaetes.

The Sand Reference Station was sampled in September 1985, and January 1986. This station was located northeast of the Massachusetts Bay Disposal Site (42°25.497, 70°31.755) along the 60 meter isopleth. Sediments from this station were coarse sand to very coarse sand. The Sand Station within the MBDS area was located in the northeastern portion of the Massachusetts Bay Disposal Site. In general the sandy stations had more species than the mud stations. Molluscs and arthropods were represented by greater number of species and individuals. Most of the species found at the mud station were present at the sand station. The sandy stations were less heavily dominated by annelids than the mud stations (85% in September and 80% in June) and the relative abundances of polychaete species in the sand stations were different. These sandy stations were dominated by the syllid, Exogone verugera, the spionid, Prionospio steenstrupi and the ampharetid, Anobothrus gracilis. The fauna includes species which are adapted for burrowing in sand such as the polychaetes, Nephtys picta, Glycera capitata and Notomastus latericus and the isopod, Calathura branchiata. Also present were polychaete species which build tubes in sand, such as Owenia fusiformis, Praxilella gracilis, and Streblosoma spiralis. Other taxa, specifically the molluscs and arthropods were represented by more species and greater number of individuals. Molluscs were represented by bivalves which generally require firm substratum. This includes species such as Astarte undata and Cyclocardia borealis which have heavy shells and short siphons, Crennella descussata, which attaches its byssal threads to coarse sediment particles, and Thyasira flexuosa. Also present in increased numbers were arthropods such as the amphipods, Unciola irrorata, Harpinia propingua and Haploops spp.

Anobothrus gracilis and Myriochele oculata are deposit feeders which appear to be adapted for hard bottoms where there is a supply of detrital food on the surface. Other deposit feeders like Mediomastus ambiseta are poorly adapted for sand and may be considered as overlapping from mud-bottom populations. Caprellid amphipods and syllid polychaetes such as Exogone prey on the sessile epifauna living on pebbles and shell.

The sand station within the MBDS area was sampled in September 1985. The area is similar to the other sand reference sites in species composition, number of individuals and relative abundance. It was dominated by the polychaetes Exogone verugera, Paraonis gracilis, and Prionospio steenstrupi.

Three samples were collected from the Mud Station On Dredged Material (42°26.443, 70°34.456) in September 1985. These samples contained the highest density of individuals found in the study. These samples were



dominated by oligochaetes which comprised approximately 25% of the individuals and by the tube dwelling spionid polychaete Spio pettiboneae (18% of the individuals). Twenty-two species had mean densities greater than 100/m<sup>2</sup>. These included a number of deposit-feeding polychaetes, whose density was equal to or greater than the densities on the adjacent mud bottom (Ninoe nigripes, Trochochaeta multisetosa, Mediomastus ambiseta, Chaetozone setosa, Tharyx marioni, Cossura longocirrata, Aricidea quadrilobata, and Paraonis gracilis) Other dominant polychaetes included, Anobothrus gracilis, a deposit feeder found at the Sand Reference Station, and suspension feeding polychaetes such as the spionid Prionospio steenstrupi and the sabellids, Chone infundibuliformis and Euchone incolor. Also included among the dominants at this station are small epifaunal predators such as Eteone trilineata and Phloe minuta. Densities of the bivalve, Thyasira flexuosa were highest at this station.

Spatial differences at the September survey and seasonal differences at the Mud Reference Station are apparent in most of the eleven dominant taxa common to all five benthic stations. An analysis of variance was performed to determine significance of these differences (See SAIC, 1987 Vol I). With the exception of Prionospio steenstrupi, there were significant among station differences for all dominant taxa. To determine where these differences exist a Scheffe test was performed. Densities were greatest at the Mud Station On Dredged Material and the Sand Reference Station. Significantly lower densities were found at the Mud Station Off Dredged Material and the Sand Station (i.e., both stations within the MBDS boundary but off the dredged material had similar densities). The only anomalous pattern is displayed by the ampharetid polychaete, Anobothrus gracilis, where an intermediate level was found at the Mud Reference Station for this taxon. Clear patterns support the hypothesis that the Mud Station On Dredged Material is distinct from the two other mud stations and the two sand stations. The two mud stations (MBDS-OFF and MBDS-REF) are statistically similar to each other as are the two sand stations.

There appears to be a seasonal component to the benthic community at the Massachusetts Bay Disposal Site. The data collected by Gilbert and others (1976) suggested that there were seasonal differences in the total number of individuals at the MBDS. In the present study, seasonal differences were observed in the mean abundance and species composition at the Mud Stations. The number of species in the 12 mud station replicates varied over time from 33 to 49. Seasonal differences in the number of species per sample were not statistically significant. There were, however, statistically significant differences in the number of individuals among season at the mud reference station. The number of individuals per sample at the mud reference station was approximately twice that of the June and January samples. Statistically significant differences in mean abundances were noted for the following species Anobothrus gracilis, Mediomastus ambiseta, Chaetozone setosa, Aricidea quadrilobata, Prionospio steenstrupi, Exogone verugera, and Thyasira flexuosa.

The results of the REMOTS survey indicate seasonal changes in biological activity at the Massachusetts Bay Disposal Site. There is abundant evidence of biological activity at the surface and deep bioturbation in September survey. Maps of the RPD depths taken October, 1984, June 1985, September 1985 and January 1986 were made (SAIC, 1987 Figures III-B.2 through III-B.5). The REMOTS survey also indicates that there are statistically significant changes in the RPD depths among seasons at the Massachusetts Bay. This seasonal pattern is most likely associated with seasonal changes in the abundance of organisms and species types rather than changes in temperature or activity level of the benthic infauna.

The data from MBDS is superficially similar to the Massachusetts Bay being largely dominated by polychaetes. The major difference between the data set collected in this report and the historic data is in the abundance of Spio limicola. Although Spio limicola was the dominant species in the historic data from Massachusetts Bay, Stellwagen Basin and the proposed disposal area, their abundances were very much reduced in the 1985-1986 samples. The reason for this difference are unknown. However, it should be noted that Spio limicola abundances were also low in other recent studies in Mass/Bay (MWRA, 1986).

In summary, the analysis of the benthic community structure in the vicinity of the Massachusetts Bay Disposal Site revealed assemblages typical of Massachusetts Bay. The 1985 to 1986 sampling program identified the dominant organisms at the reference area to be the polychaete Paranois gracilis, averaging 29.2% (S.D.=9.3, n=9) of all organisms and Heteromastus filiformis averaging 10.1% (S.D. = 4.7, n=9) of all organisms. Average overall benthic density for the three seasons investigated was 5,936 organisms per square meter (S.D. = 2,842.7, n= 9) from an average of 44 species /m<sup>2</sup> (S.D. = 9.5, n=9).

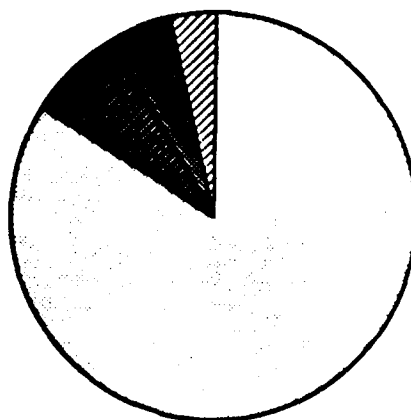
The benthic population sampled in September from a silty area within MBDS, but off dredged material (MBDS-OFF) contained similar dominance of Paranois gracilis (18.9%) for its average density of 8746 organisms /m<sup>2</sup> from 37 species (n=3). The dredged material disposal station within MBDS was clearly dominated by oligochaetes in September 1985, comprising 24.7% of its 26,548 organisms /m<sup>2</sup> from 55 species (n=3). These assemblages are typical for populations colonizing recently disturbed habitat, such as the dredged material, exploiting the available high organic content of the substrate.

The sandy reference area east of MBDS was dominated in September 1985 by the polychaete Exogone verugera, representing 15.4% of its 9190 organisms per square meter from 63 species (n=3). The sand station within MBDS was also dominated by Exogone verugera, at 20.5% of its 4622 organisms /m<sup>2</sup> from 69 species.

These results indicate benthic population impacts at the point of dredged material disposal, having higher densities of organisms colonizing the disposed dredged material. Within MBDS, but off dredged material, the high densities of oligochaetes may indicate recruitment from MBDS-ON or another type of perturbation, possibly the foraging effects of finfish such as schools of dogfish observed in the finfish sampling program (see 3.C.2). The sandy area within MBDS was similar to sandy reference areas and both reference site (outside MBDS) have typical Massachusetts Bay benthic communities.

### NMFS 12/79

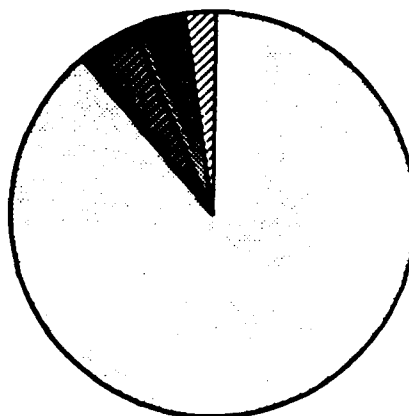
|                               |       |
|-------------------------------|-------|
| <i>Spio pettiboneae</i>       | 40.7% |
| <i>Maldane sarsi</i>          | 7.6%  |
| <i>Anobothrus gracilis</i>    | 7.0%  |
| <i>Myriochele oculata</i>     | 4.5%  |
| <i>Sternaspis scutata</i>     | 4.0%  |
| <i>Paraonis gracilis</i>      | 3.3%  |
| <i>Nucula tenuis</i>          | 3.3%  |
| <i>Tharyx sp</i>              | 2.8%  |
| <i>Prionospio steenstrupi</i> | 2.7%  |
| <i>Aricidea quadrilobata</i>  | 2.4%  |



|              |      |
|--------------|------|
| □ Annelida   | 83.9 |
| ■ Mollusca   | 7.5  |
| ■ Arthropoda | 5.1  |
| ▨ Other      | 3.5  |

### NMFS 7/80

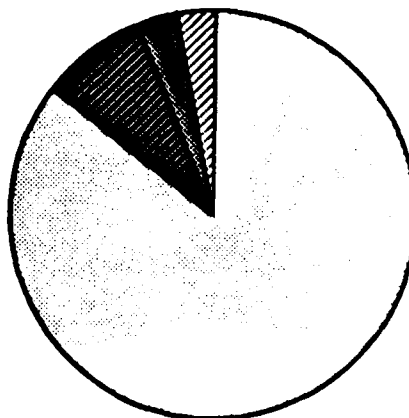
|                                |       |
|--------------------------------|-------|
| <i>Spio limicola</i>           | 11.0% |
| <i>Prionospio steenstrupi</i>  | 10.0% |
| <i>Anobothrus gracilis</i>     | 8.3%  |
| <i>Aricidea quadrilobata</i>   | 5.4%  |
| <i>Heteromastus filiformis</i> | 5.3%  |
| <i>Myriochele oculata</i>      | 5.0%  |
| <i>Sternaspis scutata</i>      | 4.2%  |
| <i>Chaetozone setosa</i>       | 3.8%  |
| <i>Scoloplos acutus</i>        | 2.0%  |
| <i>Paraonis gracilis</i>       | 1.8%  |



|              |      |
|--------------|------|
| □ Annelida   | 88.8 |
| ■ Mollusca   | 4.7  |
| ■ Arthropoda | 4.1  |
| ▨ Other      | 2.5  |

### NMFS 12/80

|                               |       |
|-------------------------------|-------|
| <i>Spio limicola</i>          | 44.0% |
| <i>Anobothrus gracilis</i>    | 10.2% |
| <i>Aricidea quadrilobata</i>  | 4.2%  |
| <i>Sternaspis scutata</i>     | 3.9%  |
| <i>Prionospio steenstrupi</i> | 3.6%  |
| <i>Myriochele oculata</i>     | 3.3%  |
| <i>Maldane sarsi</i>          | 3.3%  |
| <i>Haploscoloplos sp</i>      | 2.8%  |
| <i>Nucula tenuis</i>          | 2.3%  |
| <i>Chaetozone setosa</i>      | 1.9%  |



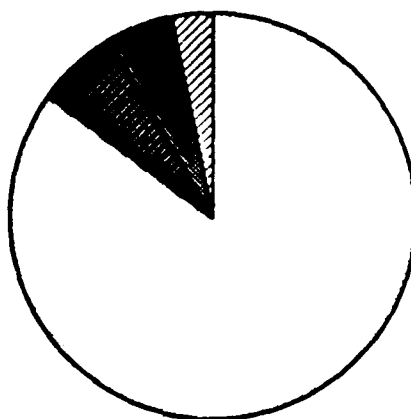
|              |      |
|--------------|------|
| □ Annelida   | 85.3 |
| ■ Mollusca   | 8.3  |
| ■ Arthropoda | 3.3  |
| ▨ Other      | 3.1  |

Figure 3.C.3-1

Benthos at NMFS Station near the disposal area. 1979-1981

### NMFS 7/81

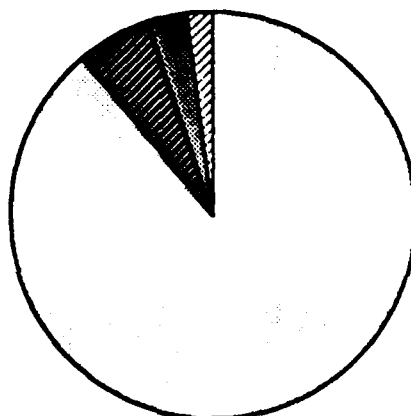
|                               |       |
|-------------------------------|-------|
| <i>Spio limicola</i>          | 43.2% |
| <i>Prionospio steenstrupi</i> | 8.2%  |
| <i>Anobothrus gracilis</i>    | 6.1%  |
| <i>Sternaspis scutata</i>     | 3.4%  |
| <i>Aricidea quadrilobata</i>  | 3.4%  |
| <i>Myriochele oculata</i>     | 3.3%  |
| <i>Maldane sarsi</i>          | 2.6%  |
| <i>Chaetozone setosa</i>      | 2.2%  |
| <i>Maldanidae sp</i>          | 1.7%  |
| <i>Haploscoloplos sp</i>      | 1.4%  |



|              |      |
|--------------|------|
| □ Annelida   | 84.9 |
| ■ Mollusca   | 6.5  |
| ■ Arthropoda | 5.4  |
| ▨ Other      | 3.2  |

### NMFS 1/82

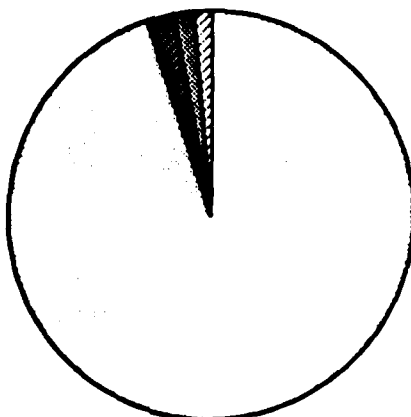
|                                |       |
|--------------------------------|-------|
| <i>Spio limicola</i>           | 39.9% |
| <i>Anobothrus gracilis</i>     | 12.9% |
| <i>Myriochele oculata</i>      | 5.5%  |
| <i>Sternaspis scutata</i>      | 5.4%  |
| <i>Aricidea quadrilobata</i>   | 3.7%  |
| <i>Maldane sarsi</i>           | 3.7%  |
| <i>Heteromastus filiformis</i> | 2.4%  |
| <i>Haploscoloplos sp</i>       | 2.2%  |
| <i>Prionospio steenstrupi</i>  | 1.6%  |
| <i>Nucula tenuis</i>           | 1.5%  |



|              |      |
|--------------|------|
| □ Annelida   | 88.9 |
| ■ Mollusca   | 5.9  |
| ■ Arthropoda | 3.4  |
| ▨ Other      | 1.8  |

### NMFS 12/82

|                               |       |
|-------------------------------|-------|
| <i>Spio limicola</i>          | 72.6% |
| <i>Anobothrus gracilis</i>    | 3.6%  |
| <i>Maldane sarsi</i>          | 3.3%  |
| <i>Prionospio steenstrupi</i> | 2.9%  |
| <i>Myriochele oculata</i>     | 1.9%  |
| <i>Polydora socialis</i>      | 1.1%  |
| <i>Sternaspis scutata</i>     | 1.0%  |
| <i>Haploscoloplos sp</i>      | 1.0%  |
| <i>Chaetozone setosa</i>      | 1.0%  |
| <i>Maldanide sp</i>           | 0.9%  |



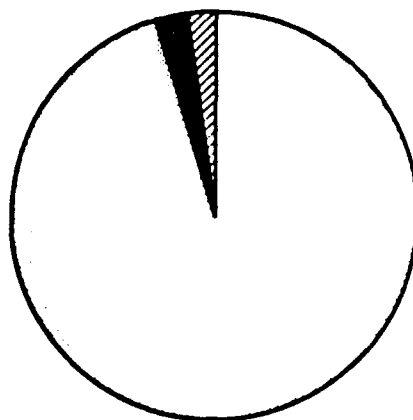
|              |      |
|--------------|------|
| □ Annelida   | 94.9 |
| ■ Mollusca   | 2.2  |
| ■ Arthropoda | 1.7  |
| ▨ Other      | 1.3  |

Figure 3.C.3-2

Benthos at NMFS Station near  
the disposal area 1981-1982

### Mud Reference 6/85

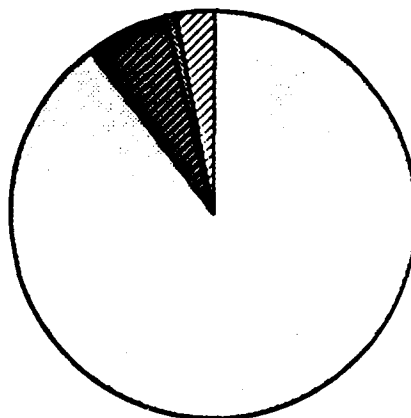
|                                |       |
|--------------------------------|-------|
| <i>Paraonis gracilis</i>       | 38.0% |
| <i>Heteromastus filiformis</i> | 12.8% |
| <i>Cossura longocirrata</i>    | 7.0%  |
| <i>Spio pettiboneae</i>        | 6.6%  |
| <i>Oligochaetes sp</i>         | 4.8%  |
| <i>Chaetozone setosa</i>       | 4.0%  |
| <i>Mediomastus ambiseta</i>    | 2.4%  |
| <i>Myriochele oculata</i>      | 2.0%  |
| <i>Trochochaeta multiseta</i>  | 2.0%  |
| <i>Prionospio steenstrupi</i>  | 1.7%  |



|              |      |
|--------------|------|
| □ Annelida   | 95.4 |
| ■ Mollusca   | 0.5  |
| ■ Arthropoda | 2.0  |
| ▨ Other      | 2.1  |

### Mud Reference 9/85

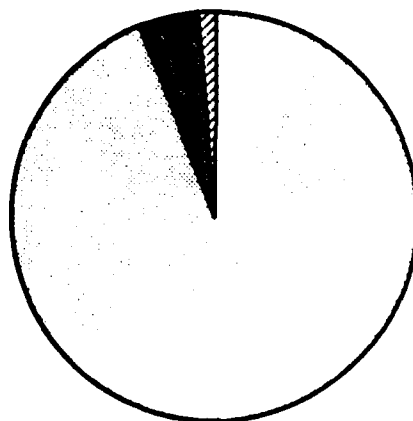
|                                |       |
|--------------------------------|-------|
| <i>Paraonis gracilis</i>       | 20.4% |
| <i>Prionospio steenstrupi</i>  | 8.3%  |
| <i>Chaetozone setosa</i>       | 7.9%  |
| <i>Mediomastus ambiseta</i>    | 7.2%  |
| <i>Oligochaete sp</i>          | 6.4%  |
| <i>Sternaspis scutata</i>      | 5.4%  |
| <i>Cossura longocirrata</i>    | 5.4%  |
| <i>Thyasira flexuosa</i>       | 5.1%  |
| <i>Heteromastus filiformis</i> | 5.1%  |
| <i>Aricidea quadrilobata</i>   | 5.0%  |



|              |      |
|--------------|------|
| □ Annelida   | 89.6 |
| ■ Mollusca   | 6.4  |
| ■ Arthropoda | 0.8  |
| ▨ Other      | 3.2  |

### Mud Reference 1/86

|                                |       |
|--------------------------------|-------|
| <i>Paraonis gracilis</i>       | 28.2% |
| <i>Heteromastus filiformis</i> | 12.4% |
| <i>Spio pettiboneae</i>        | 5.7%  |
| <i>Cossura longocirrata</i>    | 4.8%  |
| <i>Chaetozone setosa</i>       | 4.5%  |
| <i>Oligochaete sp</i>          | 4.5%  |
| <i>Myriochele oculata</i>      | 4.3%  |
| <i>Trochochaeta multiseta</i>  | 3.4%  |
| <i>Aricidea quadrilobata</i>   | 2.9%  |
| <i>Sternaspis scutata</i>      | 2.9%  |



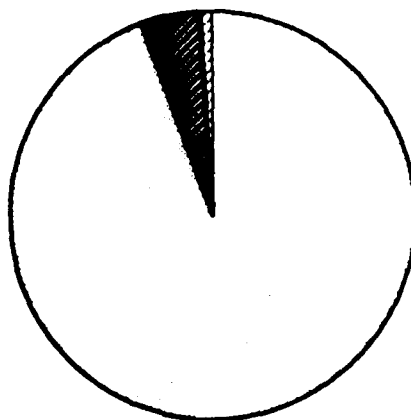
|              |      |
|--------------|------|
| □ Annelida   | 93.9 |
| ■ Mollusca   | 1.1  |
| ■ Arthropoda | 3.7  |
| ▨ Other      | 1.3  |

Figure 3.C.3-3

Benthos at the Mud Reference Site (MBDS-REF)

### Mud - On 9/85

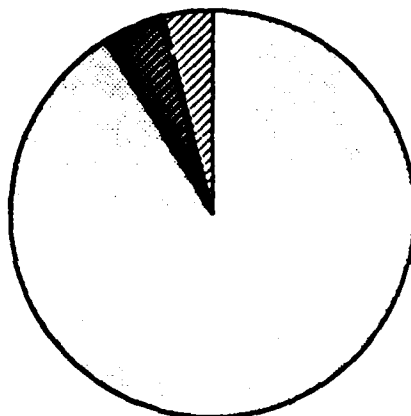
|                               |       |
|-------------------------------|-------|
| <i>Oligochaete sp</i>         | 24.7% |
| <i>Spio pettiboneae</i>       | 18.1% |
| <i>Chaetozone setosa</i>      | 8.5%  |
| <i>Mediomastus ambiseta</i>   | 6.9%  |
| <i>Prionospio steenstrupi</i> | 5.9%  |
| <i>Aricidea quadrilobata</i>  | 5.6%  |
| <i>Anobothrus gracilis</i>    | 4.7%  |
| <i>Thyasira flexuosa</i>      | 3.8%  |
| <i>Cossura longocirrata</i>   | 3.5%  |
| <i>Paraonis gracilis</i>      | 2.7%  |



|   |            |      |
|---|------------|------|
| □ | Annelida   | 94.5 |
| ■ | Mollusca   | 4.4  |
| ■ | Arthropoda | 0.4  |
| ▨ | Other      | 0.7  |

### Mud - Off 9/85

|                                |       |
|--------------------------------|-------|
| <i>Paraonis gracilis</i>       | 18.9% |
| <i>Oligochaete sp</i>          | 12.5% |
| <i>Chaetozone setosa</i>       | 9.1%  |
| <i>Mediomastus ambiseta</i>    | 8.3%  |
| <i>Heteromastus filiformis</i> | 7.6%  |
| <i>Prionospio steenstrupi</i>  | 6.5%  |
| <i>Maldane sarsi</i>           | 4.8%  |
| <i>Cossura longocirrata</i>    | 4.7%  |
| <i>Sternaspos scutata</i>      | 4.4%  |
| <i>Aricidea quadrilobata</i>   | 4.2%  |



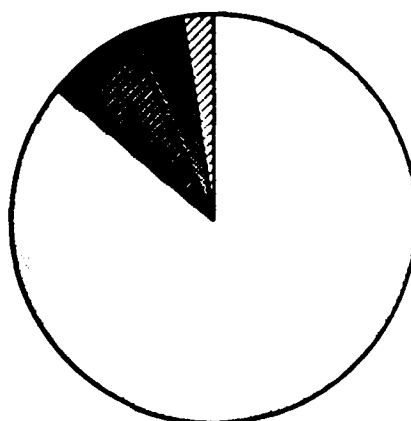
|   |            |      |
|---|------------|------|
| □ | Annelida   | 91.0 |
| ■ | Mollusca   | 4.8  |
| ■ | Arthropoda | 0.4  |
| ▨ | Other      | 3.7  |

Figure 3.C.3-5

Benthos at the Mud Stations  
in the disposal area (MBDS-ON  
and MBDS-OFF)

### Sand Reference 9/85

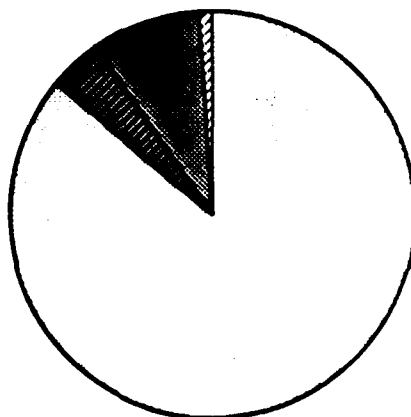
|                                |       |
|--------------------------------|-------|
| <i>Exogone verugera</i>        | 15.4% |
| <i>Prionospio steenstrupi</i>  | 14.4% |
| <i>Anobothrus gracilis</i>     | 14.0% |
| <i>Nicomache sp</i>            | 6.2%  |
| <i>Paraonis gracilis</i>       | 6.1%  |
| <i>Ampharetid sp</i>           | 5.7%  |
| <i>Myriochele oculata</i>      | 2.7%  |
| <i>Chone infundibuliformis</i> | 2.0%  |
| <i>Astarte undata</i>          | 1.9%  |
| <i>Phloe minuta</i>            | 1.9%  |



|              |      |
|--------------|------|
| □ Annelida   | 85.9 |
| ■ Mollusca   | 7.1  |
| ■ Arthropoda | 4.3  |
| ▨ Other      | 2.6  |

### Sand Reference 1/86

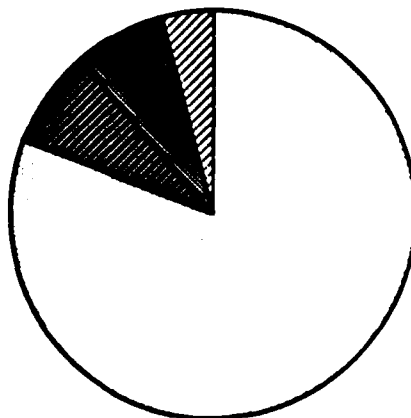
|                               |       |
|-------------------------------|-------|
| <i>Prionospio steenstrupi</i> | 21.8% |
| <i>Exogone verugera</i>       | 15.0% |
| <i>Anobothrus gracilis</i>    | 7.2%  |
| <i>Myriochele oculata</i>     | 5.2%  |
| <i>Paraonis gracilis</i>      | 5.1%  |
| <i>Praxillura longissima</i>  | 5.0%  |
| <i>Exogone hebes</i>          | 4.9%  |
| <i>Mediomastus ambiseta</i>   | 3.9%  |
| <i>Spio pettiboneae</i>       | 2.1%  |
| <i>Cossura longocirrata</i>   | 1.5%  |



|              |      |
|--------------|------|
| □ Annelida   | 86.1 |
| ■ Mollusca   | 4.2  |
| ■ Arthropoda | 8.6  |
| ▨ Other      | 1.1  |

### Sand Station 9/85

|                               |       |
|-------------------------------|-------|
| <i>Exogone verugera</i>       | 20.5% |
| <i>Paraonis gracilis</i>      | 7.9%  |
| <i>Prionospio steenstrupi</i> | 7.1%  |
| <i>Nicomache sp</i>           | 6.3%  |
| <i>Phloe minuta</i>           | 4.7%  |
| <i>Mediomastus ambiseta</i>   | 3.0%  |
| <i>Streblosoma spiralis</i>   | 2.4%  |
| <i>Goniada maculata</i>       | 2.1%  |
| <i>Phascolion strombi</i>     | 2.0%  |
| <i>Myriochele oculata</i>     | 2.0%  |



|              |      |
|--------------|------|
| □ Annelida   | 86.1 |
| ■ Mollusca   | 4.2  |
| ■ Arthropoda | 8.6  |
| ▨ Other      | 1.1  |

Figure 3.C.3-6

Benthos at the Sand Station  
(MBDS-SRF, MBDS-NES)



Table 3.C.3-1. Summary of Historic Data on Massachusetts Bay  
Percent abundance of dominant organisms in Massachusetts Bay.  
Numbers in parentheses indicates rank abundance.

|                                | Gilbert et al. 1976<br>MassBay | MBDS<br>1976 | Gilbert, 1975<br>MBDS<br>1975 |
|--------------------------------|--------------------------------|--------------|-------------------------------|
| <i>Spio (limicola)</i>         | 42% (1)                        | 32% (1)      | 29% (1)                       |
| <i>Prionospio steenstrupi</i>  | 11% (2)                        | 16% (2)      | 11% (2)                       |
| <i>Heteromastus filiformis</i> | 4% (5)                         | 7% (4)       | 11% (3)                       |
| <i>Aricidea quadrilobata</i>   | 4% (4)                         | 11% (3)      | 2% (7)                        |
| <i>Ampharete acutifrons</i>    | 3% (6)                         | 1% (9)       | 1% (8)                        |
| <i>Chaetozone setosa</i>       | 1% (7)                         | 2% (7)       | 10% (4)                       |
| <i>Thyasira gouldi</i>         | 1% (8)                         | 2% (8)       | 8% (5)                        |
| <i>Cirratulid</i>              | 7% (3)                         |              |                               |
| <i>Myriochele (heeri)</i>      |                                | 5% (5)       |                               |
| <i>Cossura longocirrata</i>    |                                | 2% (6)       |                               |
| <i>Hippomedon propinquus</i>   |                                | 1% (10)      |                               |
| <i>Golfingia</i>               |                                |              | 6% (6)                        |

Table 3.C.3-2. Location of Previous Studies in Massachusetts Bay

| Study           | Station      | Latitude   | Longitude  | Depth | Substrate |
|-----------------|--------------|------------|------------|-------|-----------|
| Gilbert<br>1975 |              | 42 25 N,   | 70 35 W    | 300'  | Soft Mud  |
| Gilbert # 11    |              | 42 27.2 N, | 70 35 W    | 265'  | Soft Mud  |
| et al # 12      |              | 42 23 N,   | 70 36 W    | 265'  | SoftMud   |
| 1976 # 13       |              | 42 22 N    | 70 32 W,   | 280   | Soft Mud  |
| # 14            |              | 42 24.6 N, | 70 30.2 W  | 265'  | Soft Mud  |
| # 15            |              | 42 22.7 N, | 70 26.2 W, | 256'  | Soft Mud  |
| NMFS            |              | 42 19.0 N, | 70 36.0 W, |       |           |
| SAIC            | Mud Ref      | 42 24.7 N  | 70 32.8 W, | 300'  | Silt      |
| 1986            | Sand Ref     | 42 25.5 N  | 70 31.8 W  | 250'  | Sand      |
|                 | Sand Station | 42 26.4 N  | 70 34.3 W  | 165'  | Sand      |
|                 | Mud On       | 42 25.9 N  | 70 34.5 W  | 255'  | Silt      |
|                 | Mud Off      | 42 24.9 N  | 70 33.9 W  | 275'  | Silt      |

### 3.C.4. Mammals, Reptiles, and Birds

Tables 3.C.4-1 through 3.C.4-4 list the mammals, reptiles, and birds anticipated to occur in the vicinity of MBDS. Regionally, the Gulf of Maine is within the range of approximately 35 species of marine mammals, four species of marine turtles and approximately 40 species of seabirds.

Dedicated aerial studies have been conducted by NED (MBO, 1987) to assess the site specific mammal, reptile, and seabird use of MBDS. While not exhaustive, the observations represent a characterization of the dominant species occurrence in the three ten minute square study area contiguous to MBDS (See Fig. 3.C.4-1). Sections 3.C.5 and 4.C.5 discuss details of these studies and the occurrence of threatened and endangered species of marine mammals and turtles, including the Humpback whale, Megaptera novaeangliae; the Fin whales, Balaenoptera physalus; and the Right whale, Eubalaena glacialis that occur in the vicinity of MBDS. Reptiles anticipated to occur at MBDS include the threatened loggerhead turtle, Caretta caretta; and the endangered Atlantic Ridley's turtle, Lepidochelys kempi; green turtle Chelonia mydas; hawksbill turtle, Eretmochelys imbricata; and leatherback turtle, Dermochelys coriacea. Site specific scientific studies in 1985-1986 identified non-endangered dominant marine mammals at MBDS to include the minke whale Balaenoptera acutorostrata; the white sided dolphin, Lagenorhynchus acutus; and the harbor porpoise, Phocoena phocoena. Non-dominant mammals that may range into the Gulf of Maine (extralimittally) include Pilot whales Globicephala melaena; grampus, Grampus griseus; killer whales, Orcinus orca; bottlenosed dolphins, Tursiops truncatus; common dolphins, Delphinus delphis; spotted dolphins, Stenella plagiodon; striped dolphins, Stenella coeruleoalba; harbor seals, Phoca vitulina; and gray seals, Halichoerus grypus. Dominant seabirds observed during these studies include northern fulmar, Fulmarus glacialis; shearwaters, Puffinus spp; storm petrels, Hydrobatidae; northern gannet, Sula bassanus; Pomarine Jaeger, Stercorarius pomarinus; gulls, Larinae; and alcids, Alcidae.

NOTE: The following species accounts do not include those organisms discussed in detail, in Section 3.C.5 of this report, entitled: "Threatened and Endangered Species."

#### Minke Whale

The minke whale, Balaenoptera acutorostrata, is the smallest member of the family Balaenopteridae. The range of the minke whale in the northwest Atlantic extends across shelf waters from Baffin Island, Ungava Island and Hudson Strait south to the Gulf of Mexico and the Caribbean Sea (Sergeant 1963; Mitchell 1974c; Leatherwood et al. 1976; Winn and Perkins 1976). Seasonal north-south, onshore and offshore movements (similar to that of the finback whale) are likely. Minke whale sightings in all but excellent conditions are limited due to the inconspicuousness of the species; therefore seasonal trends are more difficult to determine. However, during spring and summer, the range of the minke whale in the northwest Atlantic extends north from Cape Hatteras.

Minke whales occupy wide regions of the shelf, especially in spring and summer. The area of greatest abundance as described by CETAP (1982) is a U-shaped area extending east from Montauk Point, Long Island, south-east of Nantucket Shoals to the Great South Channel, then northward along the 100 m contour outside Cape Cod to Stellwagen Bank and Jeffreys Ledge.

All sightings south of Nova Scotia from Mid-April to October generally are concentrated in this region (Hain et al. 1981). In late summer, their range extends into the northern Gulf of Maine - lower Bay of Fundy. Their range is contracted in fall and winter. Although winter sightings are reported from the Gulf of Mexico (Gunter 1954), northeast Florida and the Bahamas (Katona et al. 1977) winter sightings in shelf waters southeast of Nantucket (south of 40°00' N) are rare.

Minke whales are secondary and tertiary carnivores that feed primarily on schooling fish and euphausiids (Sergeant 1963, Mitchell 1973, 1974b, 1974c, 1975c; Leatherwood et al. 1976; Jonsgard 1982). In the Gulf of Maine, minke whales eat fish, especially herring and sand eel (Katona et al. 1977).

Due to the limited detectability of this species at sea, abundance estimates based on sighting data likely are biased downward. In the Gulf of Maine, abundance estimates from shipboard surveys (MBO 1980-85) range from 30 (winter) to 520 (summer). Estimates resulting from CETAP (1982) surveys range from 0 (winter) to 113 (summer).

Minke whales commonly are observed in the northern Stellwagen/southern Jeffreys Ledge area from March until November of each year (Figs. 3.C.4-2). Overwintering in the area may occur, although survey coverage was limited during the winter period. While all areas receive some use by minkes, southern Jeffreys Ledge seems to be the preferred habitat.

Recent site specific studies have described two peaks in minke whale abundance in the study area during the year: 1) Minke whales were seen commonly in the spring, and during this time, they are usually alone, with other conspecifics in the vicinity and 2) the largest concentrations are observed during late summer and early fall. Aggregations of 15 to 20 animals are not uncommon at this time. During 1984 these concentrations were found only on Jeffreys Ledge. During 1985 they also were seen on northern Stellwagen. Aggregations of minke whales often are in the immediate vicinity of fin whales.

Surface feeding by minke whales has been reported, but most feeding seems to take place below the surface. Breaching, commonly reported in other areas, has only been observed in the MBDS area on three occasions. Only twice have minke whales small enough to be considered calves been observed within MBDS.

#### White-sided Dolphin, Lagenorhynchus acutus

In the western North Atlantic, Leatherwood et al. (1976) reported white-sided dolphins, Lagenorhynchus acutus, from Davis Strait south to Hudson Canyon (Figure 3.C.4-3). The first confirmed report of white-sided dolphins from Cape Cod occurred in 1956 (Schevill 1956). The southernmost extent of their range was redefined to the mid-Atlantic Bight near Chesapeake Bay by Testaverde and Mead (1980). This southern range limit

was supported by Hain *et al.* (1981), CETAP (1982), and Powers and Payne (1983). White-sided dolphins are widespread throughout the Gulf of Maine and Georges Bank throughout the year south to approximately 40°00' N (Hain *et al.* 1981; CETAP 1982). Within these regions they are most abundant in the southwestern Gulf of Maine. Hain *et al.* (1981) suggested that their distribution is most widespread from October to November. In the spring and fall, sightings occurred along the shelf edge from south of Nantucket to Virginia. White-sided dolphins were the most abundant (total numbers) cetacean observed by Scott *et al.* (1981) and CETAP (1982).

White-sided dolphins are tertiary carnivores reported to feed on a variety of fishes, including Atlantic herring *Clupea harengus*, silver hake *Merluccius bilinearis*, smelt *Osmerus mordax*, and squid *Illex illecebrosus* (Schevill 1956; Sergeant *et al.* 1980; Katona *et al.* 1977; 1978; Kenney *et al.* 1985). In the Gulf of Maine and on Georges Bank white-sided dolphins have been seen in close association with feeding humpback and fin whales (Katona *et al.* 1977; Hain *et al.* 1981; Mayo 1982) which are believed to be feeding on sand eel *Ammodytes americanus* (Overholtz and Nicolas 1979; Hain *et al.* 1982; Mayo 1982; Payne *et al.* 1986). Thus, it seems likely that white-sided dolphins also feed on sand eel. Most sightings of feeding in this region occurred over shelf edges, or along shelf bottoms with rugged relief, often in the presence of whales. Sightings of feeding were common in the southwest Gulf of Maine, between the 70-100m depth contours. The apparent prey during surface-feeding activity were sand eel (Mayo 1982).

White-sided dolphins in the study area were most widespread winter and spring, and most abundant in summer. This species is found year-round only in the Gulf of Maine where it is the dominant delphinid. The areas of greatest concentrations were in the south and southwest regions of the Gulf of Maine, including the MBDS study area.

#### White-beaked Dolphin *Lagenorhynchus albarostris*

The range of the white-beaked dolphin extends from approximately Cape Cod north to Greenland (Leatherwood *et al.* 1976; Katona *et al.* 1983). They are found only in the North Atlantic and are the more northerly distributed of the two *Lagenorhynchus* species, being far more numerous in waters off Canada and Greenland (Sergeant and Fisher 1957; Katona *et al.* 1977; Whitehead and Glass 1985).

Within the Gulf of Maine sightings occur most frequently between April and November from Cape Cod - Great South Channel north to include Jeffreys Basin (CETAP 1982). This species is thought to have been more common around Cape Cod in the 1950s than at present, and the apparent decline has been accompanied by an increase in sightings of white-sided dolphins (Katona *et al.* 1983).

In Canadian waters white-beaked dolphins feed on schooling fishes (herring and capelin), and squid (Van Bree and Nigssen 1964). CETAP (1982) suggested that white-beaked dolphins in the Gulf of Maine likely feed on sand eel.

Atlantic white-beaked dolphin Lagenorhynchus albirostris are common off the North Atlantic coast especially near Newfoundland. They range south to Massachusetts Bay and have been observed within the MBDS study area (Figure 3.C.4-3). They are a gregarious species feeding mainly on fish and squid. Within the study area they have been observed predominantly at the northern end of Stellwagen Bank.

#### Harbor Porpoise

The harbor porpoise Phocoena phocoena is locally abundant in temperate waters of the northern hemisphere (Figure 3.C.4-4), principally in shallow shelf waters (Gaskin et al. 1974; Leatherwood et al. 1976; Prescott and Fiorelli 1980; Gaskin 1984). They have been reported from the Davis Straits south to Cape Hatteras, North Carolina (Mitchell 1975c; Leatherwood et al. 1976; CETAP 1982; Payne et al. 1984); within this range they are most common in the Bay of Fundy and off southwest Greenland (Neave and Wright 1968; Gaskin et al. 1974; 1975; Kapel 1975, 1977; Leatherwood et al. 1976; Gaskin 1977, 1984; Prescott and Fiorelli 1980; Kraus and Prescott 1981; Kraus et al. 1983; Gaskin and Watson 1985).

The diet of harbor porpoise consists of small schooling fishes, polychaetes and cephalopods (Rae 1965; Smith and Gaskin 1974). In the Gulf of Maine herring, mackerel, squid and likely sand eel are important prey items (Katona et al. 1983).

In the Bay of Fundy and northern Gulf of Maine in summer, harbor porpoise would be classified as "abundant" in comparison with all other areas examined (Gaskin 1977). Gaskin (1977, 1984) noted that densities of harbor porpoise in the lower Bay of Fundy - upper Gulf of Maine increased in late June to mid-July, remained high in August to September, then decreased throughout fall. These results are in agreement with results obtained previously by Neave and Wright (1968). Prescott and Fiorelli (1980) indicated that the northern Gulf of Maine and the Bay of Fundy might support as much as 80% of the total summer population south of the Gulf of St. Lawrence. During the high abundance levels of summer in the northern Gulf of Maine, sightings throughout the southwestern Gulf of Maine (Jeffreys Ledge and Stellwagen Bank) and Cape Cod Bay are rare (CETAP 1982). In the winter the distribution of harbor porpoise shifts markedly to the south and offshore. Sightings are scattered throughout the lower Gulf of Maine and Georges Bank and overall numbers are drastically reduced (CETAP 1982). Sightings south of 40°00' N latitude in coastal bays increase during this period (MBO, unpublished survey data 1984-1985). Prescott and Fiorelli (1980) suggest that other offshore Banks (i.e. Grand Banks) may also provide winter habitat for this species. By mid-spring sightings of harbor porpoise again are concentrated in the southwest Gulf of Maine - Great South Channel region, on Jeffreys Ledge and in portions of coastal Maine.

Estimates of harbor porpoise abundance in summer range from approximately 8,000 to 15,000 in the Gulf of Maine - Lower Bay of Fundy

(Kraus et al. 1983) to approximately 2,500 in the Gulf of Maine only (CETAP 1982). Kraus et al. (1984) suggested that aerial surveys locate approximately 14% of the total harbor porpoise present in an area. Therefore applying this factor to the aerial estimates of CETAP (1982) results in a modified estimate of approximately 16,000 harbor porpoise in the Gulf of Maine. This is in very close agreement to the findings of Kraus et al. (1983).

Harbor porpoise Phocoena phocoena are observed in the Gulf of Maine infrequently after early spring. Sightings are common during late March and early April. Only one sighting occurred outside this period. Their distribution in the MBDS during winter is unknown. Most sightings involve small groups of two to seven animals. No more than 15 individuals have been observed in any one day. This species usually is observed on the northwest corner of Stellwagen Bank (Fig. 3.C.4-4). Preliminary data indicate that this western tip is used more than any other.

The data presented (Figure 3.C.4-4) are primarily from the observations conducted by the Cetacean Research Unit. The effort is biased in that spatial coverage of the entire study area was incomplete. The greatest effort was in the outer one-half of the study area and along the northern edge of Stellwagen Bank. Therefore the number of sightings presented are considered a minimum.

#### Pilot Whale

The Atlantic pilot whale, Globicephala melaena, is common from Greenland, Iceland, and the Faeroe Islands (Saemundsson 1939; Sergeant 1968; Kapel 1975; Mercer 1975; Mitchell 1975) south to at least Cape Hatteras (Leatherwood et al. 1976; Katona et al. 1981; CETAP 1982) and east across the north Atlantic to European waters (Brown 1961).

From Cape Hatteras to northeast Georges Bank, including the Gulf of Maine, the distribution of pilot whales generally follows the shelf edge between the 100 m and 1000 m contour (see Figure 3.C.4-5). During mid-winter to spring (December to May), sightings are reported along the shelf edge of the mid-Atlantic and southern New England regions. Throughout spring sightings increase along the shelf edge and north to, and including, Georges Bank. They are most abundant on Georges Bank from May to October (Hain et al. 1981; Powers et al. 1982). This is consistent with the findings reported by Katona et al. (1977) and CETAP (1982). During summer and fall, sightings occur on central Georges Bank north along the northern edge of the Bank, and into the central Gulf of Maine. This trend continues as pilot whales move north to the inshore Newfoundland waters by June (Sergeant and Fisher 1957; Sergeant et al. 1970).

Globicephala are tertiary consumers that are considered teuthophagous (Scott et al. 1983), feeding primarily on squid (Mercer 1975; Caldwell et al. 1971), with fish and invertebrates as alternative prey items (Sergeant

1962; Mercer 1967; Katona et al. 1977). The preferred food of Globicephala meleana, off Newfoundland, is the short-finned squid, Ilex illecebrosus, (Sergeant 1962). Food eaten when squid were not present were Atlantic cod, Gadus morhua, (Sergeant 1962) and Greenland turbot, Reinhardtius hippoglossoides, (Mercer 1967). The squid taken most commonly by G. meleana in north European waters is probably Ommastrephes sagittatus; fish observed in pilot whale stomachs from north Britain include horse mackerel, Caranx trachurus, and flatfish, (Mitchell 1975a). In our study area, the long-finned squid, Loligo pealei, and Atlantic mackerel, Scomber scombrus, have been suggested as probable prey items in the mid-Atlantic Bight during winter and spring (G. Waring, NMFS/NEFC, pers. comm.).

Pilot whales are present on Georges Bank summer through winter (Figure 3.C.4-5) with scattered sightings along the northern edge of the Bank and in the Great South Channel in fall. Thus, during the fall migration south, sightings occur over a broader area of the shelf than during the spring northward movement which occurs principally along the shelf edge. In the fall, pilot whales (Globicephala meleana) have been sighted in the northern Stellwagen/southern Jeffreys Ledge area. This species appears to prefer Jeffreys Ledge, but are seen in MBDS quadrant III (that 10' square east of MBDS) several times each year during October and November.

#### Grampus

Grampus, Grampus griseus, are widely distributed in tropical and temperate waters around the world (Leatherwood et al. 1980). In the western North Atlantic, grampus occur from eastern Newfoundland to the Lesser Antilles (Leatherwood et al. 1976) into the Gulf of Mexico (Gunter 1954; Paul 1968; Fritts and Reynolds 1981).

The center of grampus sightings along the eastern United States occurs along the shelf-edge-slope waters from Cape Hatteras north to Georges Bank (36°00' N to 41°00' N) during spring, summer and fall (Hain et al. 1981; CETAP 1982; Powers and Payne 1983). Grampus generally are considered absent from the Gulf of Maine, although individuals have been recorded.

A single sighting of grampus (Grampus griseus) occurred in August 1985. A pod of 15 to 25 individuals was sighted regularly in the waters of northern Stellwagen for a two week period. The pod contained three to four calves, several adult females, several juveniles, and one to two adult males. Occurrence of this species at this location is considered uncommon.

#### Killer Whale, Orcinus orca

In the western north Atlantic, killer whale, Orcinus orca, sightings are widespread, but sporadic. They occur from near pack-ice south into the Gulf of Mexico (Leatherwood et al. 1976; Schmidly 1981), although

generally they are more common in cooler waters and in productive coastal regions (Katona et al 1976; CETAP 1982). Killer whales are thought to follow the schools of bluefin tuna, Thunnus thynnus, which move into these waters during late-summer as part of their annual migration. All sightings by CETAP (1982) occurred in shelf waters outside the Gulf of Maine.

Killer whales are opportunistic feeders, feeding on a wide variety of fish, pinnipeds and cetaceans (Leatherwood et al. 1976; Whitehead and Glass 1985). In the Gulf of Maine, tuna, mackerel, and herring to be likely prey items Katona et al. (1983). This species most likely would be infrequent foragers in the study area.

#### Bottlenose Dolphin

Bottlenosed dolphins, Tursiops truncatus, are distributed worldwide in warm and temperate waters (Katona et al. 1977). Bottlenosed dolphins are common along the east coast of the United States from Nova Scotia to Florida, westward into the Gulf of Mexico and south to Venezuela (Hain et al. 1981; Katona et al. 1977; Leatherwood et al. 1976; Fritts and Reynold 1981, Marcuzzi and Pilleri 1971; Payne et al. 1984; Powers and Payne 1983; Sergeant et al. 1970).

Sightings of bottlenosed dolphins within the Gulf of Maine occur in late summer to fall, but these appear extralimital. This species generally is considered absent from the Gulf of Maine and were not observed at MBDS.

#### Common Dolphin

Common dolphins, Delphinus delphis, have been reported throughout the temperate and tropical waters of the Atlantic (Leatherwood et al. 1976) and Pacific Oceans (Evans 1974). In the western North Atlantic, they have been reported off Nova Scotia (Sergeant and Fisher 1957, Leatherwood et al. 1976), throughout the shelf waters off the eastern United States into the Gulf of Mexico (Fritts and Reynolds 1981), and south to Venezuela (Leatherwood et al. 1976).

Common dolphins are widespread from Cape Hatteras northeastward to the eastern tip of Georges Bank (35°00' N to 42°00' N) in mid-to-outer shelf waters (Hain et al. 1981; CETAP 1982; Powers et al. 1982; Powers and Payne 1983), on a year-round basis. Sightings in the Gulf of Maine are limited to fall and winter, and generally occur on the northeastern edge of Georges Bank. Common dolphins, therefore, are considered year-round residents south of the Gulf of Maine, and occur as stragglers into the Gulf of Maine, especially in fall and winter.



## Spotted and Striped Dolphins

The Spotted Dolphin, Stenella plagiodon and Striped Dolphin, Stenella coeruleoalba, are not anticipated to occur in the vicinity of MBDS. The Spotted Dolphin has never been recorded in the Gulf of Maine and the Striped Dolphin are infrequently recorded there.

## PINNIPED SPECIES

### Harbor Seal

The harbor seal, Phoca vitulina is the most abundant pinniped species occurring in the eastern United States. They are common from Labrador to Long Island, New York, and are found occasionally as far south as South Carolina (Brimley 1931) and Florida (Caldwell and Caldwell 1969). Though not the dominant species, they also are quite prevalent in eastern Canada. Along the eastern North American coast, harbor seals are widely distributed in nearshore waters.

Harbor seals are opportunistic feeders, eating species which are regionally and seasonally dominant (Boulva 1976; Pitcher 1980a, 1980b; Brown and Mate 1983), with a preference for small, schooling fishes (Boulva and McLaren 1979). Katona et al. (1983) report that seals feed on fish and invertebrates as available, primarily herring, squid, alewife, flounder and hake. However, after analysing fecal samples collected south of Maine, Payne et al. (1985) report two distinct faunal communities taken by seals in southern New England. The community of fishes selected by harbor seals from the Isle of Shoals, New Hampshire was diverse, and was representative of the bottom fishes characteristic of the relatively deep waters of the Gulf of Maine. These included: redfish (Sebastes marinus), cod (Gadus morhua), herring (Clupea harengus) and yellowtail flounder (Limanda ferruginea). In contrast, the prey selected from the relatively shallow waters adjacent to Cape Cod was numerically dominated (99%) by sand eel (Ammodytes americanus) (Payne et al., 1985).

Harbor seals prefer sheltered and undisturbed rocky ledge haulout sites of coastal bays and estuaries from Maine south to Plymouth, Massachusetts, and isolated sandy beaches and shoals south of Plymouth. Their present breeding range in the northwest Atlantic extends from ice-free waters of the Arctic to New Hampshire, though previously harbor seals bred as far south as Cape Cod Bay in the first half of the twentieth century (Katona et al., 1983). They are now only seasonal residents in southern New England (south of Maine), appearing in late September and remaining until late May (Payne and Schneider, 1984). The present geographical and breeding ranges probably are a direct result of a state-offered bounty on harbor seals in southern New England which remained in effect in Massachusetts until 1962. The bounty undoubtedly resulted in an overall reduction of seal numbers throughout southern New England, limited southward dispersion of seals from Maine rookeries (Payne and Schneider, 1984), likely led to the extirpation of breeding activity south of Maine

(Katona et al., 1983), and the present seasonal occurrence of harbor seals south of Maine. To date, all breeding activity, which occurs from late April to mid-June (Katona et al., 1983), takes place north of Massachusetts.

Since the passage of the Marine Mammal Protection Act in 1972, the abundance of harbor seals in New England has increased steadily. The greatest concentration of seals occurs along the northern Maine coast in Machias and Penobscott Bays, and off Mount Desert and Swans Islands (Katona et al. 1983). Current population estimates derived from aerial surveys show that the Maine population is increasing and is now 12,000 to 15,000 animals (Katona et al. 1983). Approximately 4000 seals (25% of the New England population) overwinter south of Maine; 60% of these animals occur on, or adjacent to, Cape Cod, Massachusetts (Payne et al. 1985). Transient individuals may be found in the vicinity of MBDS boundary, but this area is not a significant habitat for Harbor Seals.

#### Gray Seal

Gray Seals, Halichoerus grypus, are the most abundant pinnipeds in the southern reaches of eastern Canada from Labrador south through the Bay of Fundy. Approximately 40,000 to 50,000 inhabit the Canadian Maritimes, and that stock is expanding (Beck 1983; Katona et al. 1983). Small colonies in the Gulf of Maine are found in the Grand Manan archipelago of the Bay of Fundy (Richardson et al. 1974). Non-breeding colonies also are located in the Mt. Desert Rock - Penobscott Bay area (Katona et al. 1983). Katona et al. (1983) estimated a total of approximately 600 gray seals in the Maine area. A small population occurs south of Cape Cod, with emigration of individuals from Maine to this colony possibly occurring across the study area.

Gray seals consume fish and invertebrates as available, the most common food items in the Bay of Fundy and eastern Canada are herring, cod, flounder, skate, squid, and mackerel (Beck 1983; Katona et al. 1983). Sherman (1983) suggests that the Nantucket gray seals feed primarily on skates, alewives, and sand eel; all of which are abundant in that area from mid-winter to late spring.

The Massachusetts population of 70 or more gray seals in the early 1940's was reduced by bounty killing to 20 or less by 1963 when the bounty was repealed (Sherman 1986). This population, located southwest of Nantucket Island, is the only actively breeding population in the eastern United States. Pupping occurs in mid-winter, although pup production has been very low in recent years (Sherman, 1983). Despite the low pupping rate of the Nantucket population, the total overwintering population in Massachusetts exceeded 100 animals in 1986 (MBO, unpubl. data). This recent population growth probably is due to the immigration of seals from eastern Canada where the stock is expanding rapidly (Rough, in press). This hypothesis is strengthened by the repeated occurrence of animals in

southern New England that were tagged as pups on Sable Island, Nova Scotia (Beck 1983; Sherman 1983). This species may transit the MBDS study area, but it is not a significant habitat for Gray Seals.

#### SEABIRD SPECIES

Approximately forty species or species-groups of marine birds are found throughout the year in the waters of the Gulf of Maine. These include gulls, alcids, jaegers, phalaropes, gannets, terns, scoters, fulmars, shearwaters, petrels, kittiwakes, mergansers and cormorants.

The occurrence of these species is based on data collected by observers from the Manomet Bird Observatory aboard research vessels conducting standardized surveys in these waters between 1980-85. The seasonal distribution of seabirds is listed in Table 3.C.4-5.

Seasonal population densities of the ten most abundant seabird species inshore and offshore of the disposal area are listed in Table 3.C.4-6.

#### SEABIRDS

##### Northern Fulmar

With respect to the MBDS, the northern fulmars Fulmarus glacialis, were recorded inshore of the disposal site only in spring, while offshore of the disposal site in waters including, and contiguous to, the Massachusetts Bay, fulmars were recorded spring-fall. Greatest densities in this area occurred in the fall.

##### Shearwaters

As in the entire Gulf of Maine, greater shearwaters (Puffinus gravis) were the most abundant shearwater in waters adjacent to MBDS. Greatest densities occurred in the summer and fall, and there was a marked increase in the densities of birds offshore of the disposal site relative to waters inshore of the disposal site. Sooty shearwaters (Puffinus griseus) were seen adjacent to the MBDS only in summer and Cory's shearwaters (Puffinus diomedea) were recorded only in summer. No manx shearwaters (Puffinus puffinus) were observed in the study area.

##### Storm-petrels

Adjacent to the MBDS, Wilson's storm-petrels (Oceanites oceanicus), were very common in summer, although much greater densities were recorded offshore of the disposal site.

## Northern Gannet

Gannets, Sula bassanus, are abundant in the Gulf of Maine fall through spring, being uncommon only north and east of Cape Cod in summer. Greatest densities occur from Stellwagen Bank south through the Great South Channel in fall. In fall, most of the birds are subadults, while in spring, the majority of birds are adults. In relation to the MBDS, gannets were abundant in waters within and adjacent to the Massachusetts Bay from fall through spring and were the most abundant bird recorded during the winter-spring aerial surveys. Large concentrations were observed feeding near feeding groups of cetaceans. There was no appreciable difference in the densities recorded between waters inshore and offshore of the disposal site.

## Phalarope spp.

Red phalaropes (Phalaropus fulicarius) were not recorded in waters adjacent to the MBDS or in any season as the majority of birds remain offshore during their migrations. Northern phalaropes (Phalaropus lobatus) generally migrate closer to the coast. This species was recorded only in summer in waters contiguous to the disposal site (Table 3.C.4-7).

## Jaeger spp.

Pomarine jaegers (Stercorarius pomarinus) were the only jaegers recorded and they were observed near the MBDS in both summer and fall.

## Gulls

Herring gulls (Larus argentatus), and great black-backed gulls, (Larus marinus), were abundant in waters adjacent to the disposal site throughout the year (Tables 3.C.4-5). There was no apparent difference in the density of birds found inshore of the disposal site and the density recorded offshore of the disposal site. During the aerial surveys, both herring and great black-backed gulls were observed in large flocks attending fishing vessels and feeding aggregations of cetaceans.

Black-legged kittiwakes, Rissa tridactyla, occurred near the disposal site in large numbers in the fall and were the most abundant bird species recorded in winter (Tables 3.C.4-5).

## Alcid.

Alcids were commonly recorded near the MBDS in winter and spring.

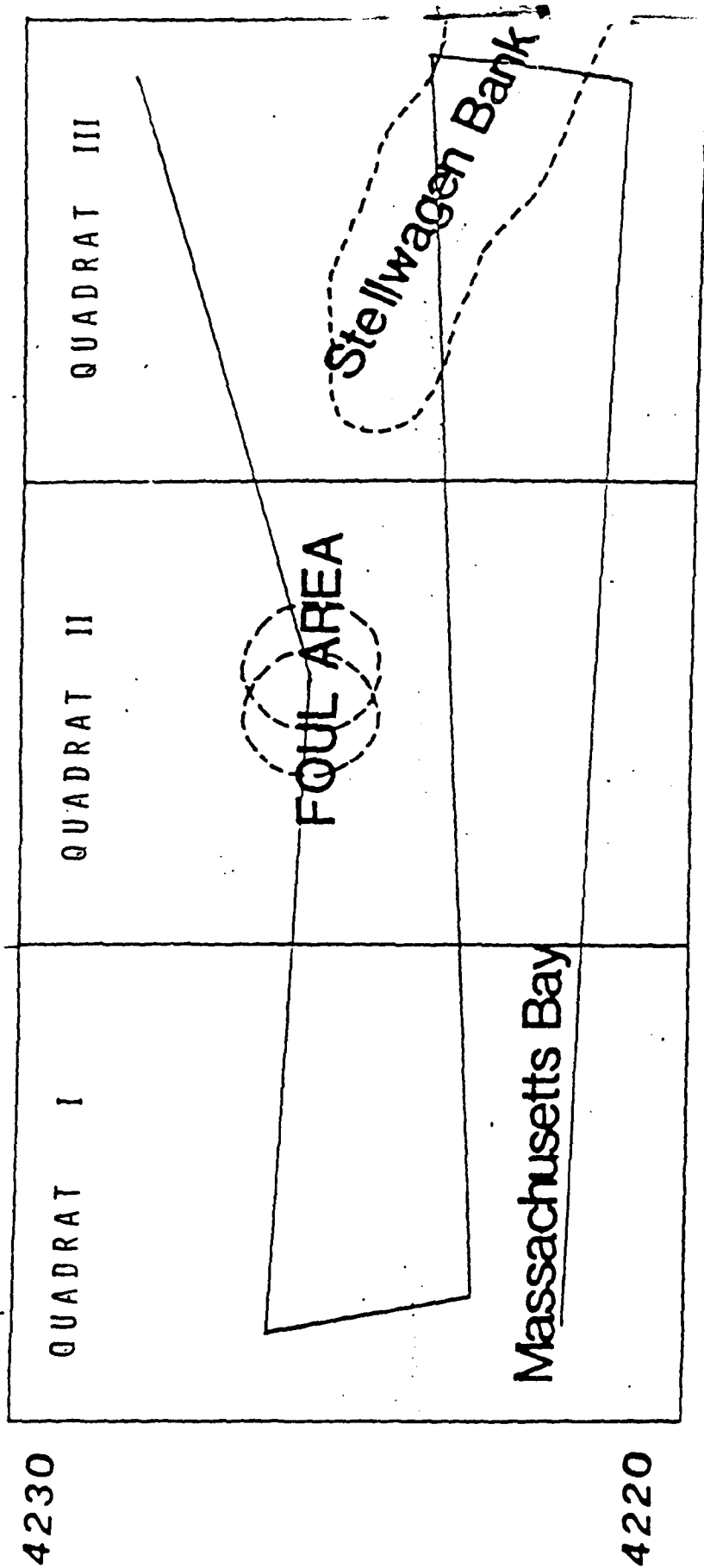


Figure 3.C.4-1: An outline of the study area showing the location of the Massachusetts Bay and the northwest corner of Stellwagen Bank relative to the flight path of the aerial survey.

Figure 3.C.4-2a: Relative distribution and abundance of minke whales in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.

Relative Abundance  
cetaceans per 10'x10' block

- 1 - 9
- 10 - 99
- >100

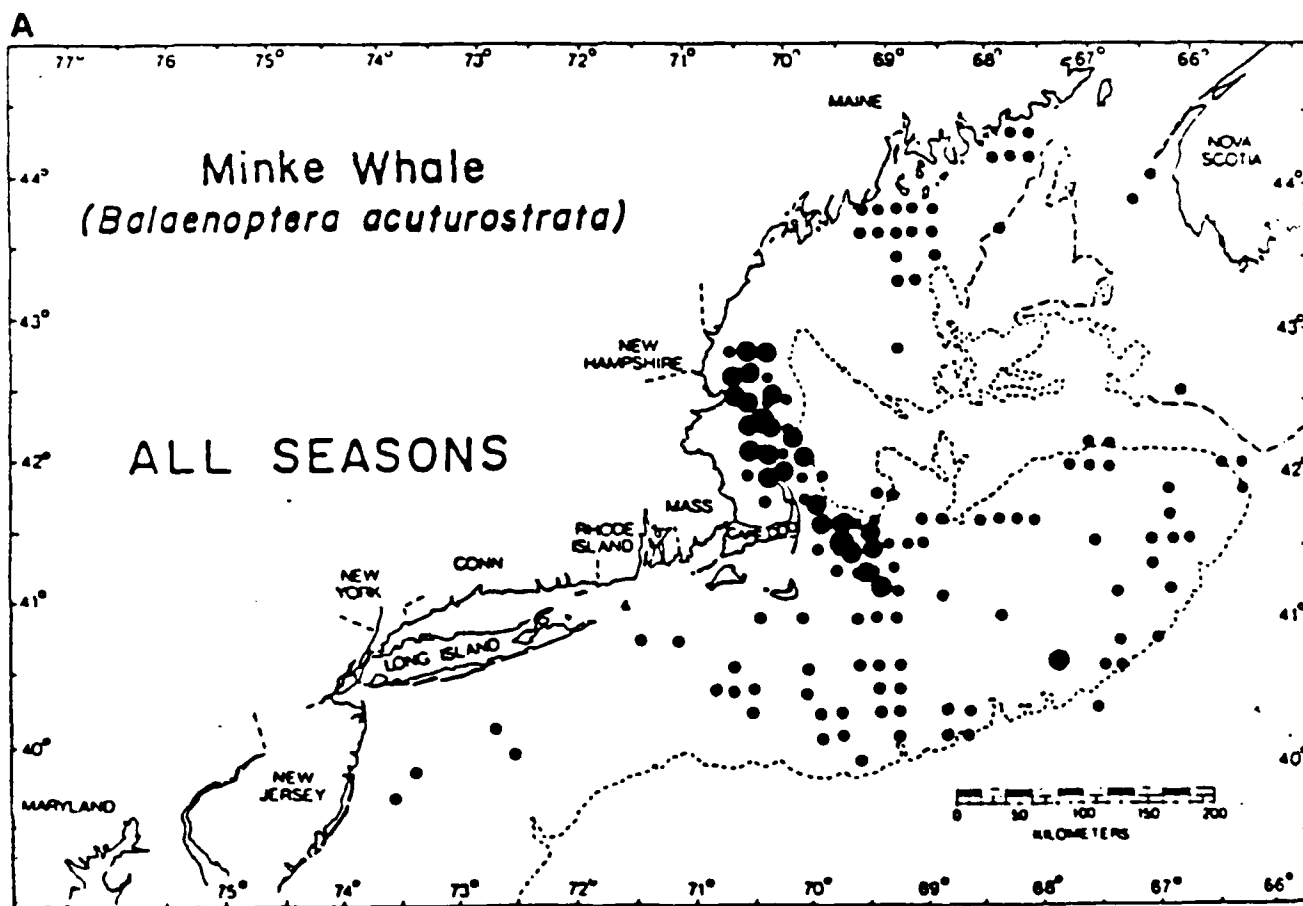


Figure 3.C.4-2b: **Sightings of Minke whales within the waters of the Massachusetts Bay study area by season.**

Sources: Data from the Cetacean Research Unit; Hain et al. 1981; Payne et al. 1984; MBO unpubl. data, 1985-1986; Gulf of Maine Cetacean Sighting Network 1975-1981; and from aerial surveys conducted during this study, see Chap V., this report.

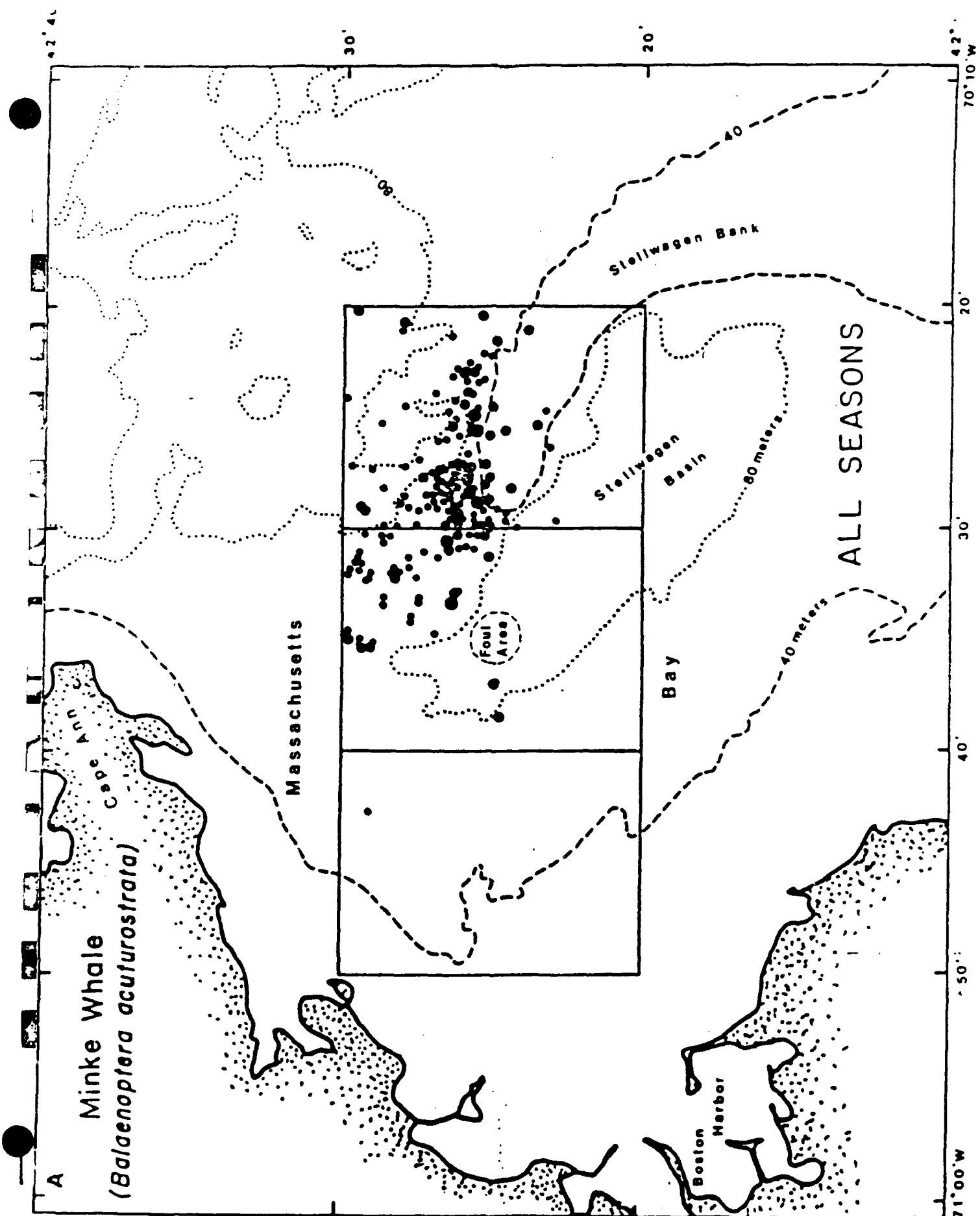




Figure 12.1.30: Relative distribution and abundance of white-sided dolphins in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.

Relative Abundance  
cetaceans per 10'x10' block

- 1 - 9
- 10-99
- >100

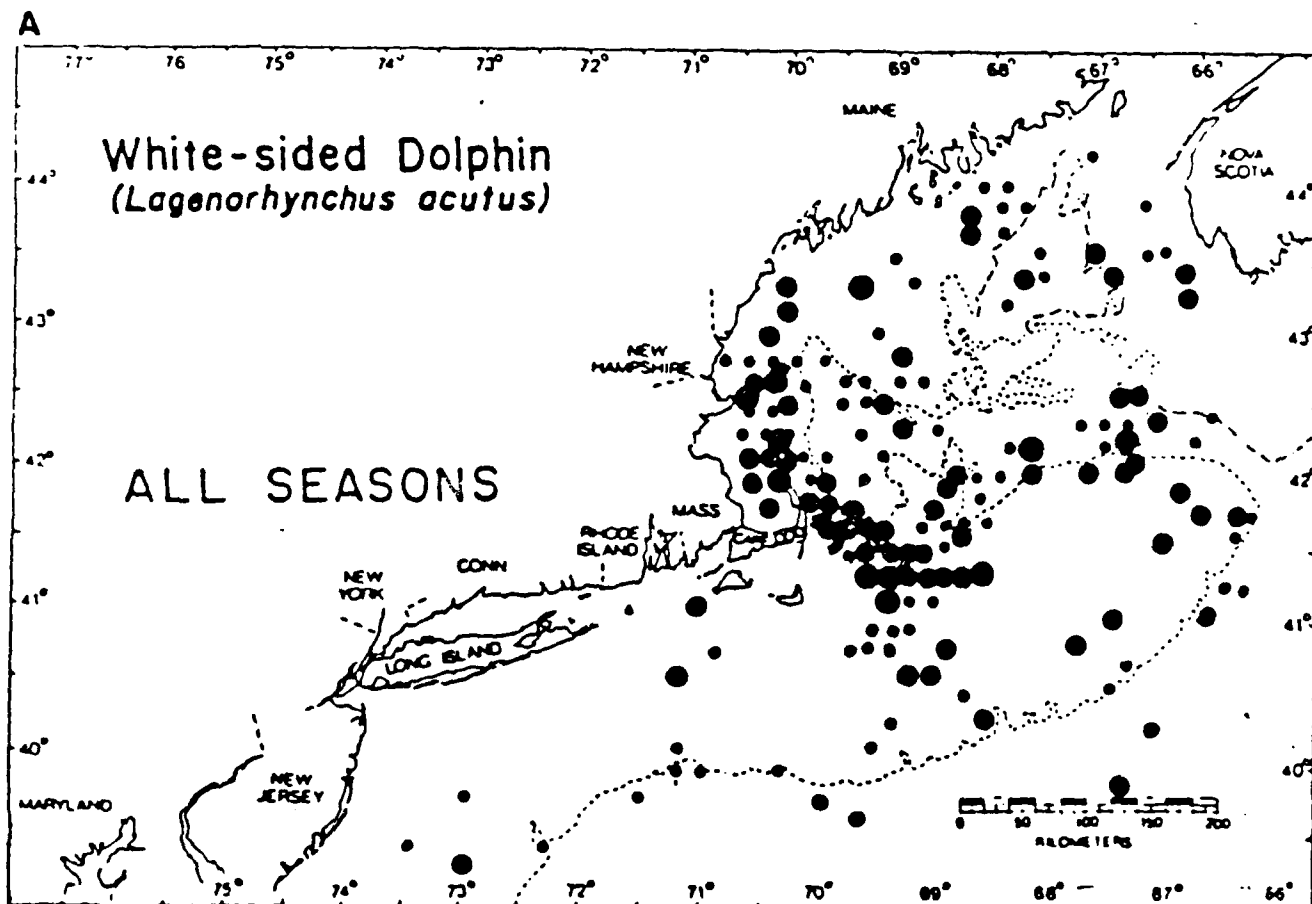


Figure 3.C.4-3b: Sightings of white-sided dolphins within the waters of the  
Mass. Bay Disposal Site study area by season.

Sources: Data from the Cetacean Research Unit; Hain et al. 1981;  
Payne et al. 1984; MBO unpubl. data, 1985-1986; Gulf of  
Maine Cetacean Sighting Network 1975-1981; and from  
aerial surveys conducted during this study, see Chap. V.,  
this report.

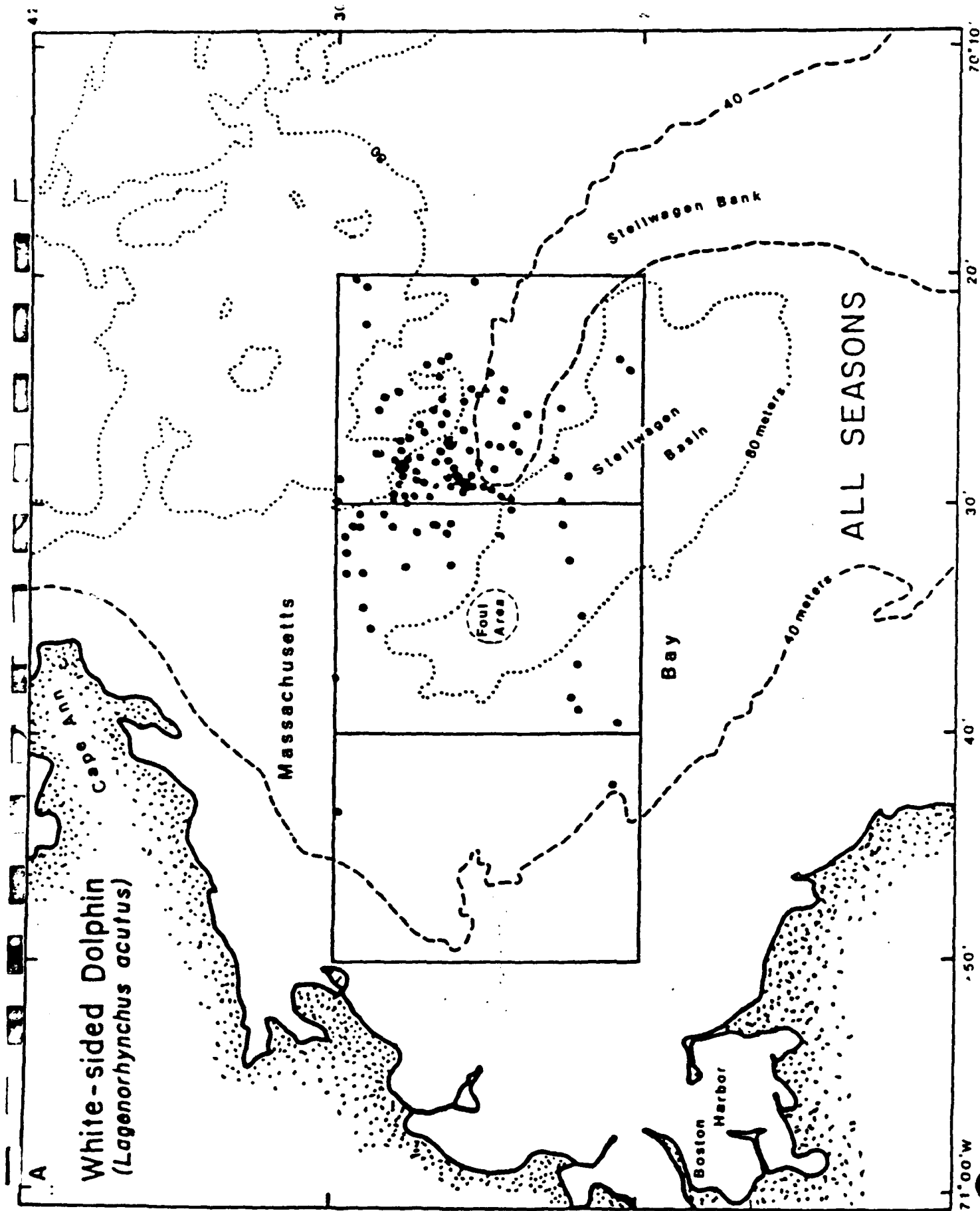


Figure 3.C.4-4a: Relative distribution and abundance of harbor porpoise in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.

Relative Abundance  
cetaceans per 10'x10' block

- 1 - 9
- 10 - 99
- >100

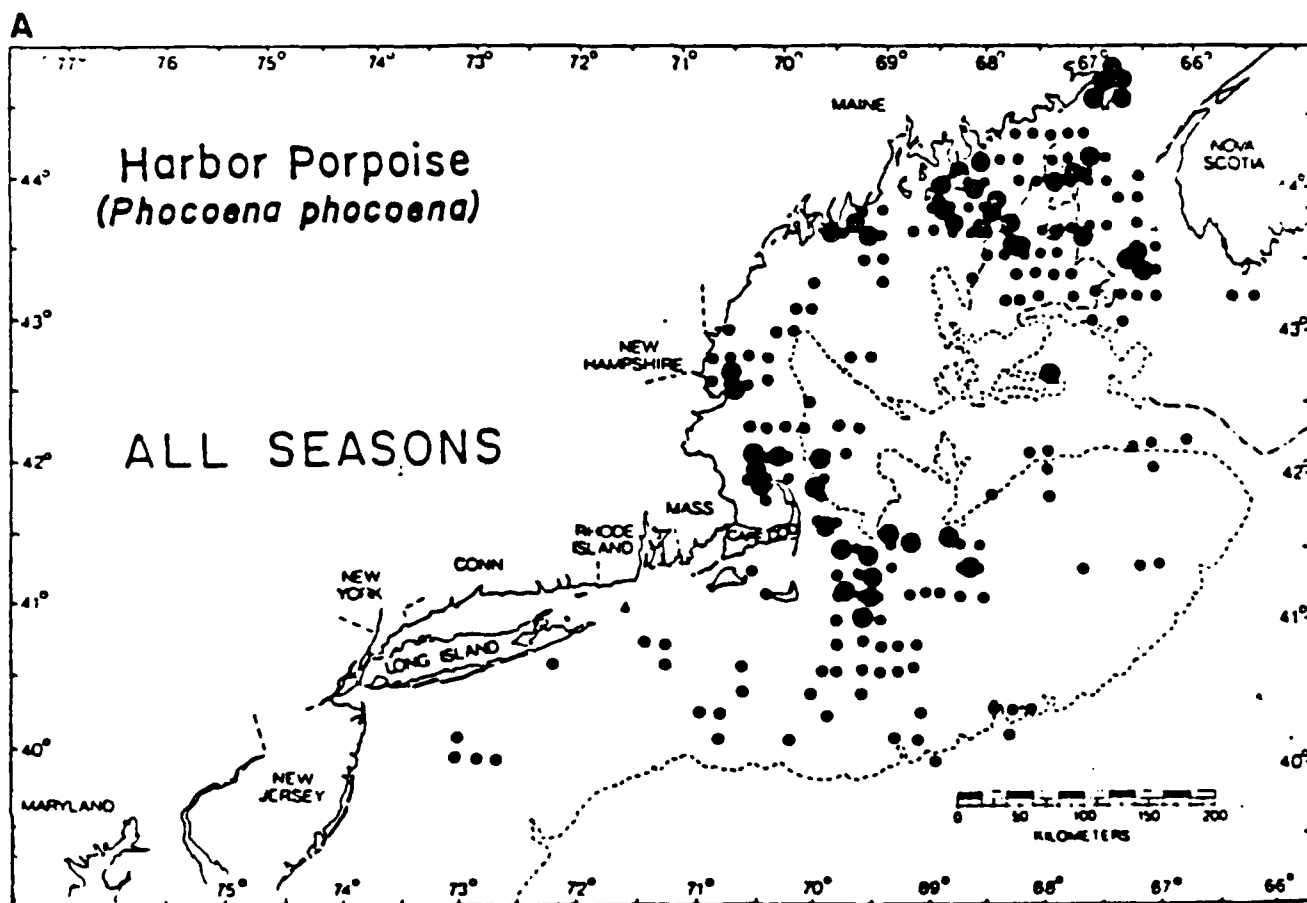


Figure 3.C.4-4b: Sightings of harbor porpoise within the waters of the Mass. Bay Disposal Site study area for all seasons.

Sources: Data from the Cetacean Research Unit; Hain et al. 1981; Payne et al. 1984; MBO unpubl. data, 1985-1986; Gulf of Maine Cetacean Sighting Network 1975-1981, and from aerial surveys conducted during this study, see Chap. V., this report.

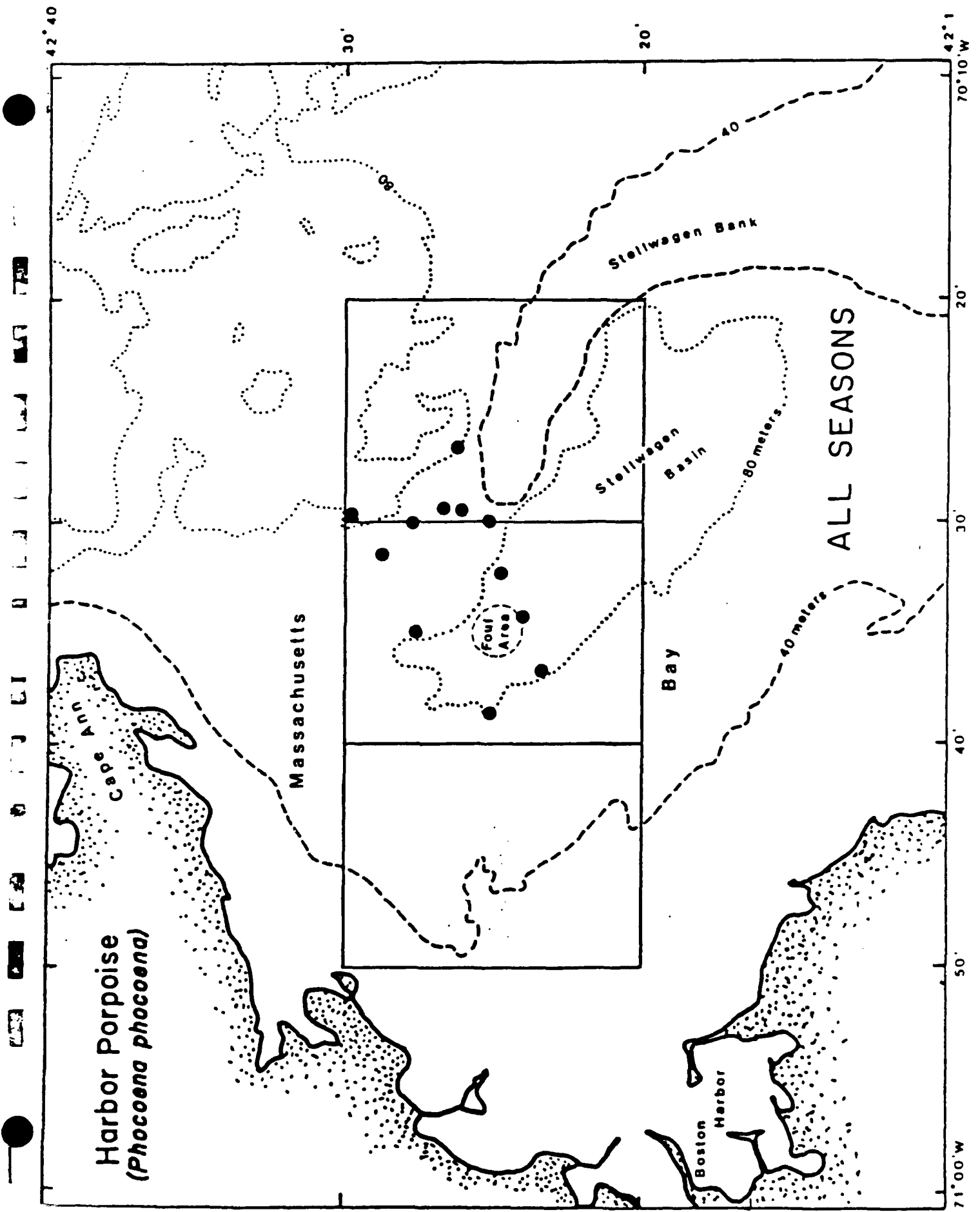


Figure 3.C.4-5: Relative distribution and abundance of pilot whales in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.

Relative Abundance  
cetaceans per 10'x10' block

- 1 - 9
- 10 - 99
- >100

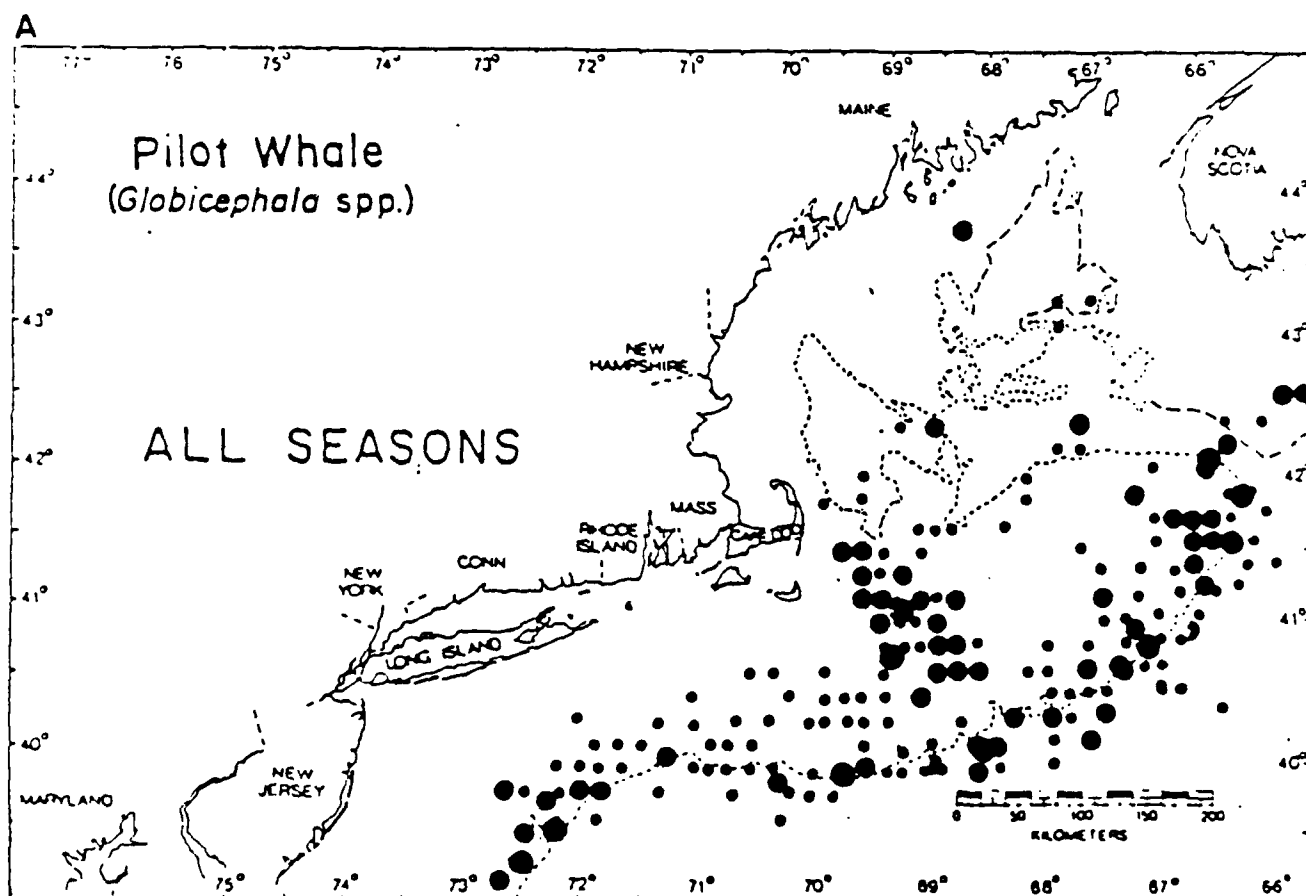


Table 3.C.4-1. List of whales, dolphins and porpoises (order Cetacea) which commonly occur in the waters of the Gulf of Maine, including Georges Bank.

Suborder Mysticeti (Baleen Whales)

Family Balaenopteridae

|                |                                   |            |
|----------------|-----------------------------------|------------|
| Finback Whale  | ( <u>Balaenoptera physalus</u> )  | Endangered |
| Minke Whale    | ( <u>B. acutorostrata</u> )       | Endangered |
| Sei Whale      | ( <u>B. borealis</u> )            | Endangered |
| Humpback Whale | ( <u>Megaptera novaeangliae</u> ) | Endangered |

Family Balaenidae

|                      |                                |            |
|----------------------|--------------------------------|------------|
| Northern Right Whale | ( <u>Eubalaena glacialis</u> ) | Endangered |
|----------------------|--------------------------------|------------|

Suborder Odontoceti (Toothed Whales)

Family Phocoenidae

|                 |                              |
|-----------------|------------------------------|
| Harbor Porpoise | ( <u>Phocoena phocoena</u> ) |
|-----------------|------------------------------|

Family Delphinidae

|                           |   |
|---------------------------|---|
| Bottlenosed Dolphin       | ( <u>Tursipos truncatus</u> )           |
| Spotted Dolphin           | ( <u>Stenella plagiodon/attenuata</u> ) |
| Striped Dolphin           | ( <u>S. coerueoalba</u> )               |
| Common Dolphin            | ( <u>Delphinus delphis</u> )            |
| White-sided Dolphin       | ( <u>Lagenorgynchus acutus</u> )        |
| White-beaked Dolphin      | ( <u>L. albirostris</u> )               |
| Grampus (Rissa's Dolphin) | ( <u>Grampus griseus</u> )              |
| Long-finned Pilot Whale   | ( <u>Globicephala melaena</u> )         |
| Killer Whale              | ( <u>Orcinus orca</u> )                 |

Family Physeteridae

|             |                                   |            |
|-------------|-----------------------------------|------------|
| Sperm Whale | ( <u>Physeter macrocephalus</u> ) | Endangered |
|-------------|-----------------------------------|------------|

Source: Hain et al. 1981; CETAP 1982; Katona et al. 1983;  
Payne et al. 1984.



Table 3.C.4-2. List of whales, dolphins and porpoises (Order Cetacea) which occur uncommonly (from sight records or strandings) in waters of the Gulf of Maine, including Georges Bank.

Suborder Mysticeti (Baleen Whales)

Family Balaenopteridae

|            |                                  |            |
|------------|----------------------------------|------------|
| Blue Whale | ( <u>Balaenoptera musculus</u> ) | Endangered |
|------------|----------------------------------|------------|

Suborder Odontoceti (Toothed Whales)

Family Delphinidae

Family Monodontidae

|        |                                  |
|--------|----------------------------------|
| Beluga | ( <u>Delphinapterus leucas</u> ) |
|--------|----------------------------------|

Family Physeteridae

|                   |                            |
|-------------------|----------------------------|
| Pygmy Sperm Whale | ( <u>Kogia breviceps</u> ) |
|-------------------|----------------------------|

Family Ziphiidae

|                            |                                    |
|----------------------------|------------------------------------|
| Northern Bottlenosed Whale | ( <u>Hyperoodon ampullatus</u> )   |
| Dense-beaked Whale         | ( <u>Mesoplodon densirostris</u> ) |
| True's Beaked Whale        | ( <u>M. mirus</u> )                |
| North Sea Beaked Whale     | ( <u>M. bidens</u> )               |

Source: Katona et al. 1983

Table 3.C.4-3. List of rare (r) and commonly (c) occurring marine turtles (Order Testudines) in the waters of the Gulf of Maine, including Georges Bank.

Family Cheloniidae

|                      |                                   |                |
|----------------------|-----------------------------------|----------------|
| Loggerhead Turtle    | ( <u>Caretta caretta</u> )        | Threatened (c) |
| Green Turtle         | ( <u>Chelonia mydas</u> )         | Endangered (r) |
| Kemp's Ridley Turtle | ( <u>Lepidochelys kemp</u> )      | Endangered (r) |
| Hawksbill Turtle     | ( <u>Eretmochelys imbricata</u> ) | Endangered (r) |

Family Dermochelyidae

|                    |                                 |                |
|--------------------|---------------------------------|----------------|
| Leatherback Turtle | ( <u>Dermochelys coriacea</u> ) | Endangered (s) |
|--------------------|---------------------------------|----------------|

Source: French (1986)

Table 3.C.4-4. List of rare (r) and commonly (c) occurring pinnipeds in coastal waters of the Gulf of Maine.

Family Phocidae (True or Hair Seals)

|             |                                 |     |
|-------------|---------------------------------|-----|
| Harbor Seal | <u>Phoca vitulina concolor</u>  | (c) |
| Ringed Seal | <u>P. hispida</u>               | (r) |
| Gray Seal   | <u>Halichoerus grypus</u>       | (c) |
| Harp Seal   | <u>Pagophilus groenlandicus</u> | (r) |
| Hooded Seal | <u>Cystophora cristata</u>      | (r) |

Family Odobenidae

|                 |                                   |                |
|-----------------|-----------------------------------|----------------|
| Atlantic Walrus | <u>Odobenus rosmarus rosmarus</u> | fossil records |
|-----------------|-----------------------------------|----------------|

Source: Katona et al. 1983

Table 3.C.4-5 Seasonal occurrence of seabirds in the Gulf of Maine.

| <u>Species</u>                                       | <u>Winter</u> | <u>Spring</u> | <u>Summer</u> | <u>Fall</u> |
|--|---------------|---------------|---------------|-------------|
| Common Loon<br><u>Gavia immer</u>                    | X             | X             | X             | X           |
| Red-throated Loon<br><u>Gavia stellata</u>           |               | X             |               | X           |
| Northern Fulmar<br><u>Fulmarus glacialis</u>         | X             | X             | X             | X           |
| Cory's Shearwater<br><u>Puffinus diomedea</u>        |               |               | X             | X           |
| Greater Shearwater<br><u>Puffinus gravis</u>         | X             |               | X             | X           |
| Sooty Shearwater<br><u>Puffinus griseus</u>          |               |               |               | X           |
| Manx Shearwater<br><u>Puffinus puffinus</u>          |               |               | X             | X           |
| Leach's Storm-Petrel<br><u>Oceanodroma leucorhoa</u> |               |               |               | X           |
| Wilson's Storm-Petrel<br><u>Oceanites oceanicus</u>  |               | X             | X             | X           |
| Northern Phalarope<br><u>Phalaropus lobatus</u>      | X             | X             | X             | X           |
| Pomarine Jaeger<br><u>Stercorarius pomarinus</u>     | X             |               |               | X           |
| Parasitic Jaeger<br><u>Stercorarius parasiticus</u>  |               | X             | X             | X           |
| Glaucous Gull<br><u>Larus hyperbureus</u>            | X             |               |               | X           |
| Iceland Gull<br><u>Larus glaucoides</u>              |               | X             |               | X           |
| Great Black-backed Gull<br><u>Larus marinus</u>      | X             | X             | X             | X           |

|  |   |   |   |   |
|--|---|---|---|---|
| Herring Gull<br><u>Larus argentatus</u>                  | X | X | X | X |
| Ring-billed Gull<br><u>Larus delawarensis</u>            | X |   | X | X |
| Laughing Gull<br><u>Larus artricilla</u>                 | X | X | X | X |
| Bonaparte's Gull<br><u>Larus philadelphia</u>            |   |   | X |   |
| Black-legged Kittiwake<br><u>Rissa tridactyla</u>        | X | X |   | X |
| Cross Tern<br><u>Sterna hirundo</u>                      |   |   | X | X |
| Arctic Tern<br><u>Sterna paradissea</u>                  |   |   |   | X |
| Least Tern<br><u>Sterna albifrons</u>                    |   |   |   | X |
| Alcidae spp  |   | X | X | X |
| White-winged Scoter<br><u>Melanitta deglandi</u>         | X | X | X | X |
| Black Scoter<br><u>Melanitta negri</u>                   | X |   |   | X |
| Surf Scoter<br><u>Melanitta perspicillata</u>            | X | X |   | X |
| Common Eider<br><u>Somateria mollissima</u>              | X | X |   | X |
| Red-breasted Merganser<br><u>Mergus serrator</u>         | X |   |   | X |
| Double-crested Cormorant<br><u>Phalacrocorax auritas</u> | X | X | X | X |
| Great Cormorant<br><u>Phalacrocorax carbo</u>            | X |   |   | X |
| Oldsquaw<br><u>Clangula hyemalis</u>                     | X | X |   | X |

### 3.C.5 Threatened and Endangered Species

Section 3.C.4. discusses in detail the distribution of non-endangered mammals, turtles and seabirds in the MBDS area. This section discussed the occurrence of the threatened or endangered species including Humpback whale (Megaptera novaeangliae), Fin whale (Balaenoptera physalus), Right whale (Eubalaena glacialis), Blue whale (Balaenoptera musculus), Sei whale (Balaenoptera borealis), and Sperm whale (Physeter macrocephalus), all Federally listed endangered species in accordance with the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.). Additionally the threatened Loggerhead turtle (Caretta caretta), and the endangered turtles: Atlantic Ridley's (Lepidochelys kempi), the Green turtle (Chelonia mydas), the Hawksbill turtle (Eretmochelys imbricata), and the Leatherback turtle (Dermochelys coriacea) are discussed.

In 1985-1986 the New England Division, COE, contracted a study of the occurrence of marine mammals, turtles and seabirds in the waters included within, and adjacent to the Foul-Area Disposal Site (MBDS) in the Massachusetts Bay. The Gulf of Maine, including Massachusetts Bay, is within the seasonal range of five species of endangered cetaceans and three species of endangered or threatened sea turtles. In addition, approximately 30 species of marine mammals and four species of marine turtles (Tables 3.C.4-1 through 4) occur within the boundaries of the Gulf of Maine.

The shelf waters of the northeastern United States can be separated into three major oceanographic regimes -- the Gulf of Maine, Georges Bank and the mid-Atlantic Bight (Fig. 3.C.5-1) which differ from one another in terms of bottom topography, sea water temperature and salinity (Bumpus 1976; Edwards 1983). Movement of large mammals and turtles are studied over regional bases because of their extensive migratory ranges. The NED investigations used available data and site specific observations.

The study consisted of regional synthesis of species movement plus a concentration of NED sponsored observations (fly-overs and shipboard observers) in the three 10-minute squares surrounding the disposal site bounded on the north by 42°30'N, on the west by 70°50'W and on the east by 70°20'W (Fig. 3.C.5-2). The westernmost 10' quadrat (Quadrat I) extends to the entrance of Boston Harbor. The principal feature of the middle 10' quadrat (Quadrat II) is Stellwagen Basin which is bounded by the 80 m contour. MBDS occurs within this quadrat at the northern end of Stellwagen Basin. Stellwagen Basin extends into the easternmost 10' quadrat (Quadrat III to the edge of Stellwagen Bank). Stellwagen Bank is a highly productive area and the principal oceanographic feature of the easternmost 10' quadrat of the study area (See Fig. 3.C.5-2).

To assist in site evaluation, NED synthesized available primary data on the distribution and abundance of cetaceans, marine turtles and seabirds within the Gulf of Maine, including Georges Bank. The available data for cetaceans can be broadly classified into two categories: 1)

standardized surveys from which analytical assessments of whale distribution and abundance, both spatial and temporal, can be made; and 2) opportunistic sighting data from which site-specific distribution patterns can be obtained.

The six data bases used in this study are: 1) the Bureau of Land Management-sponsored Cetacean and Turtle Assessment Program (CETAP) 1978-1980; 2) the National Marine Fisheries Service, Northeast Fisheries Center-sponsored marine mammal surveys conducted by the Manomet Bird Observatory (MBO), Manomet, Massachusetts 1980-1985; 3) the Right Whale Surveys of Cape Cod Bay, Center for Coastal Studies (CCS), Provincetown, Massachusetts 1983-1986; 4) the Cetacean Research Unit (CRU) of the Gloucester Fisherman's Museum, Gloucester, Massachusetts 1980-1985; 5) the Gulf of Maine Cetacean Sighting Network 1975-1981, located at the College of the Atlantic, Bar Harbor, Maine, and 6) data from NED sponsored aerial surveys conducted at the Massachusetts Bay Disposal Site, January through June 1986.

The CETAP surveys (aerial) and MBO surveys (shipboard) provide abundance estimates of all species by season and region, as well as patterns of distribution and abundance that are directly comparable. Data from the standardized Right Whale Surveys of Cape Cod Bay (CCS) were used in the discussion of their abundance, distribution and high-use habitat evaluation. Data from the aerial surveys were used in the discussion of relative densities and abundance (population) estimates of endangered cetaceans in the waters of the MBDS study area, January - June, 1986. Specific methodologies used in the aerial surveys are discussed in the following sections.

### 3.C.5.a Cetaceans

#### Humpback Whale

Kellogg (1929) suggested two stocks of the endangered humpback whales Megaptera novaeangliae, exist in the North Atlantic which were tied to the continental margins on either side of the ocean. Several individual stocks of humpbacks have been suggested in the northwest Atlantic (Katona et al. 1982). In the northwest Atlantic (see Figure 3.C.5-3), the major summer concentrations of humpbacks occur off the coast of Newfoundland and Labrador, and off the coasts of New England in the Gulf of Maine (Katona et al. 1980; Whitehead et al. 1982). During this period, feeding is their principal activity. The major winter concentrations occur along the Antillean Chain in the West Indies, principally on Silver and Navidad Banks which lie north of the Dominican Republic (Winn et al. 1975; Balcomb and Nichols 1978; Whitehead and Moore 1982). Conception and calving are the primary activities in this region. The migratory routes between regions of winter breeding and summer feeding occur in the deeper, slope waters off the continental shelf (Hain et al. 1981; Kenney et al. 1981; CETAP 1982; Payne et al. 1984, 1986). For the Gulf of Maine stock, the

Great South Channel has been suggested (Kenney et al. 1981; Payne et al. 1986) as the major exit/entry between the offshore migration routes and the Gulf of Maine feeding areas.

Between mid-March and November, humpback whales are located throughout the Gulf of Maine (north of 40°00'N latitude) (Hain et al. 1981; Kenney et al. 1981; CETAP 1982; Payne et al. 1984; Mayo et al. 1985). CETAP (1982) reported only ten winter sightings between 1978 and 1981. Payne et al. (1984) confirmed these low figures via shipboard surveys. Within this spatial and temporal framework, concentrations are greatest in a narrow band between 41°00' and 43°00'N latitudes, from the Great South Channel north along the outside of Cape Cod to Stellwagen Bank and Jeffreys Ledge.

Humpback whales are secondary and tertiary carnivores and have been described as generalists in their feeding habits (Mitchell 1974b). The principal prey of humpbacks in the Gulf of Maine are small, schooling fishes including: Atlantic herring (Clupea harengus), mackerel (Scomber scombrus), pollock (Pollachius virens), and the American sand eel (Ammodytes americanus) (Caskin 1976; Katona et al. 1977; Watkins and Schevill 1979; Karus and Prescott 1981). In recent years, observations of feeding humpback (Hain et al. 1982; Hays et al. 1985; Mayo et al. 1985; Weinrich 1985) indicate that sand eel are an important prey item in the Gulf of Maine. Overholtz and Nicolas (1979) suggested that humpback and fin whales were feeding on sand eel on Stellwagen Bank. Hain et al. (1982) identified sand eel in 50% and 75% of the feeding observations on Stellwagen Bank during 1978 and 1979 respectively. Sand eel were the only confirmed prey eaten by humpback whales between 1975-79 on Stellwagen Bank (Mayo 1982). Kenney et al. (1981) and Payne et al. (1986) suggest that the observed distribution of the Gulf of Maine humpbacks is due to the distribution of sand eels, although feeding behavior (as described by Hain et al. 1982) and bottom topographies also are critical factors in the foraging strategy of humpbacks.

In the northwest Atlantic, humpback whales have been exploited heavily since the 16th century (Mitchell and Reeves 1983). In 1915, only a few hundred humpbacks were reported to remain in the northwest Atlantic (Sergeant 1966). This species was officially protected from commercial whaling in 1965 (Sergeant 1966). Most of the recent knowledge on the biology, stock discreteness and population size of humpbacks has been the result of a technique of individual identification based on the markings of the underside of the flukes (tail) which are unique to each individual (Schevill and Backus 1960; Katona and Kraus 1979; Katona and Whitehead 1981; Katona et al. 1982). Mayo et al. (1985) provide photographs of the flukes of 216 individual whales photographed between 1976 and 1984.

Population estimates and abundance estimates for humpback whales in the north Atlantic presently range from 2,000 - 6,000. In the Gulf of Maine, the estimate for humpback whales based on minimum count (fluke identification technique) ranges from approximately 200-300 individuals

(Katona et al. 1984). Abundance estimates from aerial surveys in the Gulf of Maine between 1978-1980 ranged from 0 (winter) to approximately 600 (summer) for data both corrected and uncorrected for dive times (Scott et al. 1981; CETAP 1982). Estimates from shipboard surveys, 1980-85 range between 30 (winter) to approximately 320 (summer and fall) (MBO, unpubl. data).

Use of the northern Stellwagen waters (including the water surrounding the MBDS) by humpbacks varies both annually and seasonally. Concentrations of whales are greatest in the summer and early fall and lowest in winter and early spring (Figs. 3.C.5-3a-f) with certain exceptions. August 1985, saw little use, although this is a month in which many humpbacks are resident on northern Stellwagen. Similarly, spring of 1984 involved a higher than normal abundance of humpbacks.

One of the most important uses of Stellwagen Bank by cetaceans is for feeding, however, the intensity of surface feeding behavior on northern Stellwagen Bank is quite variable. During 1980, 1981, as well as brief periods in 1982 through 1985, feeding on Stellwagen was very active. Groups of up to 100 humpbacks were commonly found feeding on sand eel. Most members of the groups were adults, and most were using the bubble cloud feeding style described by Hain et al. (1982) and Mayo et al. (1985). Prey, when identified, were sand eel on all but eight observations; those eight involved feeding on dense concentrations of euphausiids. Although humpbacks 1-3 years old were seen surface feeding at this time, they were observed feeding much less often than adults. The Cetacean Research Unit (CRU) believe that these young whales engage in more sub-surface feeding. Feeding was observed less frequently in the immediate vicinity of the MBDS than on northern Stellwagen Bank.

In 1982 and 1983, southern Jeffreys Ledge was the site of similar feeding groups. This area received some use by feeding humpbacks in the fall of 1984 as well.

The short-term movements of humpback whales within the northern Stellwagen system appear to be dictated primarily by prey availability. Some locations on Stellwagen consistently receive high use, while other areas in the immediate vicinity of Stellwagen receive high use only periodically. For example, in October of 1985, most of the humpbacks were observed in the vicinity of the study area.

#### Fin Whale

Fin whales Balaenoptera physalus, an endangered species, are the most cosmopolitan and abundant of the large baleen whales (Reeves and Brownell 1982). They also are the most widely distributed whale, both spatially and temporarily, over the shelf waters of the northwest Atlantic (Leatherwood et al. 1976), occurring as far south as Cape Lookout, North Carolina and penetrating far inside the Gulf of St. Lawrence (see Figure 3.C.5-6).



In the shelf waters of the Gulf of Maine, including Georges Bank, the frequency of fin whale sightings increases from spring through the fall (Hain et al. 1981; CETAP 1982; Powers and Payne 1982; Payne et al. 1984, Chu 1986). The areas of Jeffreys Ledge, Stellwagen Bank and the Great South Channel have the greatest concentrations of whales during spring through fall. There is a decrease in on-shelf sightings of fin whales in winter. However, fin whales do overwinter in the Gulf of Maine. This is especially apparent on Stellwagen Bank and within the Great South Channel.

In the northern hemisphere, fin whales are considered secondary and tertiary, euphagous carnivores feeding on schooling fishes, euphausiids, and copepods depending on seasonal availability (Jonesgard 1966; Mitchell 1974; Sergeant 1966, 1977; Katona et al. 1977; Brodie et al. 1978; Overholtz and Nicholas 1979; Watkins and Schevill 1979; Mayo 1982). In the Gulf of Maine, schooling fishes are the apparent preferred prey, principally Atlantic herring (Clupea harengus) and American sand eel (Ammodytes americanus). All the coastal waters of Massachusetts and Maine waters are considered to be major feeding grounds for fin whales (Chu 1986).

Available estimates of abundance for regions of the North Atlantic range upward of tens of thousands. Eastern Canada (Nova Scotia to western Newfoundland) has the greatest concentrations, with numbers ranging from approximately 6,000 - 12,000 animals (Mitchell 1972, 1973a, 1974a). In the Gulf of Maine, the estimated number of fin whales shows clear seasonal fluctuations. Data collected between 1980-85 from shipboard observations (MBO unpublished) result in seasonal estimates between 151 (winter) to 1,862 (summer). These estimates are lower than those obtained from sighting data collected during aerial surveys in 1978-80 which were corrected for the diving behavior of the animals (CETAP 1982). CETAP's (1982) estimates for the Gulf of Maine show a peak in abundance in spring at approximately 3,000 individuals which dwindles to approximately 200 animals in winter. Both data sets show greatest densities occurring from Jeffreys Ledge and Stellwagen Bank south along the 100m contour outside of Cape Cod and into the Great South Channel. Concentrations of fin whales also are found along the boundary between the Gulf of Maine and the northern edge of Georges Bank.

Fin whales are found in the waters of northern Stellwagen Bank year-round. Although there is an overall decrease in the number of fin whales within the Gulf of Maine in winter, CETAP (1982) found little, if any, decrease in the number of fin whales present in Massachusetts Bay.

Fin whales are more widely distributed within the MBDS study area than are humpback whales (Figs. 3.C.6-3a through e). However, like humpbacks, fin whales will aggregate to feed. Concentrations of up to 50 fin whales have been observed in the northern Stellwagen area. Fin whales have shown a relatively consistent pattern of habitat use between years. Surface feeding behavior by fin whales has been observed on Stellwagen

Bank. In all but one observation the prey was sand eel. Fin whales on Jeffreys Ledge, however, appear to feed consistently on euphasids (S. Mercer, pers. comm.)

Fin whale cow/calf pairs were most frequently observed from late spring to summer. Approximately 10 to 14 fin whale cow/calf sightings have occurred each year. Most sightings occur on the northern edge of Stellwagen's tip (within the study area) although some sightings have occurred inshore toward Gloucester.

Residence time of individual fin whales in the study area is minimal. Most animals were sighted for a period of one to seven days. Individual movements are widespread within the Gulf of Maine within a season. Fin whales photographed at northern Stellwagen and southern Jeffreys have been matched to photographs taken as far away as Bar Harbor, Maine, and the Great South Channel.

Among the three 10' blocks surrounding MBDS, the offshore block receives the highest use, particularly on the western side. The middle quadrat containing MBDS, receives moderate to heavy use based on aerial surveys conducted during this study, primarily from spring through fall. The innermost quadrat receives most use by fin whales during the winter months.

#### Northern Right Whale

The north Atlantic right whale, Eubalaena glacialis, is one of the most endangered large whales in the world. It has been suggested that the north Atlantic has two stocks of right whales. The first, along the eastern North Atlantic, between the Bay of Biscay and the coast of Iceland (Allen 1908), is thought to have disappeared, (Reeves and Brownell 1982). The northwest Atlantic stock (see Figure 3.C.5-7) occurs from Nova Scotia and Newfoundland (Sergeant 1966; Mitchell 1974b, 1974c; Sutcliffe and Brodie 1977; Hay 1985b), into the lower Bay of Fundy (Arnold and Gaskin 1972; Kraus and Prescott, 1981, 1982, 1983; Reeves et al. 1983; Kraus et al. 1984;) and throughout the Gulf of Maine south to Cape Cod Bay and the Great South Channel (Watkins and Schevill 1976, 1979, 1982) in the spring and summer. In the winter, right whales occur from Cape Cod Bay (Watkins and Schevill 1976) south to Georgia and Florida (Moore 1952; Layne 196; Kraus et al. 1984; Kraus 1986) and into the Gulf of Mexico (Moore and Clark 1963; Schmidley 1981).

Between December and March, small numbers of right whales occur in waters of the Gulf of Maine and western Georges Bank. Another wintering ground for this species occurs in the Georgia-Florida Bight where possibly newborn calves have been observed (Kraus et al. 1984; Kraus 1986). Approximately 10-20 right whales are sighted annually at this location. Identification of individuals based on callosity patterns on the head (Watkins and Schevill 1982; Payne et al. 1983) has linked this wintering group with those whales that move into the Gulf of Maine - lower Bay of

Fundy during the spring and summer (see Fig. 10 from Kraus et al. 1984). In the spring, right whale concentrations in the Gulf of Maine occur principally in three locations, the Great South Channel, Cape Cod Bay north to Jeffreys Ledge, and the northern Gulf of Maine - lower Bay of Fundy. A few right whales have been reported in Massachusetts waters through the summer, however most of the population spends the summer and fall in the Bay of Fundy and on the Scotian shelf (Kraus et al. 1984; Kraus 1986). Movements of individual right whales within the Gulf of Maine have been well documented (Kraus et al. 1984).

Right whales feed almost exclusively on copepods and euphausiids. Surface feeding or "skimming" is frequently observed in the Gulf of Maine and Cape Cod Bay (Watkins and Schevill 1976; Mayo et al., this report). Feeding whales follow an erratic path when observed from the air or plotted against plankton patches and can be seen to follow "discrete patches of plankton" (Watkins and Schevill 1976, 1979; Mayo et al.). Watkins and Schevill (1976) suggest that subsurface feeding is the more typical feeding mode, rather than surface "skimming". Prey items of right whales in the Gulf of Maine and Cape Cod Bay include copepods (Calanus finmarchicus) and adult juvenile euphausiids, Thysanoessa inermis (Allen 1916; Watkins and Schevill, 1976).

Right whales have been protected from commercial hunting since 1935; however "best estimates" for the north Atlantic population are no more than a few hundred (Mitchell 1973a, 1974b; Winn et al. 1981). The largest single sighting (70-100 whales) occurred in 1970 in Cape Cod Bay (Watkins and Schevill, 1982). Much of the entire northwest Atlantic population likely moves through the Gulf of Maine on a seasonal basis. Estimates from shipboard surveys for the Gulf of Maine (MBO 1980-85) range from 0 in winter and fall, to 14 in summer and 166 in spring.

Right whales are known to occur in the northern Stellwagen Bank and southern Jeffreys Ledge regions; however information on their occurrence, movements and behavior is limited. Most sightings have occurred in the spring, during March to April, although a second peak in sighting frequency occurs in July. Right whales were not recorded within the MBDS study site during the dedicated aerial surveys.

Survey coverage of the region during early spring was limited to one year, 1985. In that year, during mid-April, a considerable number of right whales were observed approximately one mile south of quadrant II. During four days of effort between 18 and 21 April, 20 - 30 individuals were observed at that location. They were most concentrated on 18 April. Behaviors observed included courtship, breaching, and apparent juvenile play behavior (rolling, hanging with mouth opened, and investigating the vessel). Two mother/calf pairs were identified.

During the same period, lower numbers of right whales were seen on northern Stellwagen (east of MBDS). Right whales were observed on two of four cruises to northern Stellwagen during the period between 8 April and

24 April. A total of seven animals were identified, including two mother/calf pairs. Both mother/calf pairs were also seen in the large concentration south of quadrant 11. Behaviors seen on northern Stellwagen included breaching, and possible nursing.

Although survey effort on northern Stellwagen Bank during April was limited prior to 1985, one right whale was seen during the only cruise taken in April of 1983, and two were observed during a cruise in March of 1982. Throughout the spring months, northern Stellwagen is an important area for right whales, although not used as consistently or by the same numbers that frequent Cape Cod Bay during the same period (see below). Although surface feeding is frequently observed in Cape Cod Bay, it was not observed on northern Stellwagen.

The second period of right whale sightings takes place in July. Observations have been concentrated on northern Stellwagen; hence the lack of sightings in other areas does not indicate absence. During this period most animals were traveling to the north or northeast, apparently in a migratory pattern. This corresponds to known movement patterns of right whales between Cape Cod Bay and the Bay of Fundy. Many of the animals sighted in the vicinity of MBDS have been resighted in the Bay of Fundy within four to six weeks (S. Krause, pers. comm.). Mother/calf pairs were most frequently observed during July; 55% of the nine sightings during this period have been mothers with calves. Right whales make another appearance in the fall, during October and November. At this time, they are seen rarely on northern Stellwagen, but are seen with some frequency on Jeffreys Ledge (S. Mercer, pers. comm.).

#### Sei Whale

The sei whale (Balaenoptera borealis), also an endangered species, is found in all the world's oceans, excluding tropical and extreme polar seas. Evidence suggests that two stocks of sei whales occur in the northwest Atlantic (Mitchell and Chapman, 1977); one off eastern Nova Scotia and another centered in the Labrador Sea. In the western North Atlantic, this species ranges from Greenland and Iceland south to southern New England waters. Sightings in the shelf waters off the northeastern United States occur along the outside of Georges Bank and generally not in the three ten-minute squares study area around MBDS. Sei whales were observed twice on northern Stellwagen. In both cases a lone sei whale was observed in a fin whale aggregation. Sei whales are considered incidental visitors nearshore.

#### Blue Whale

In the western North Atlantic, the blue whale (Balaenoptera musculus), an endangered species, has been reported from pack ice south to the Panama Canal Zone (Leatherwood et al. 1976); however their distribution generally is more restricted. The normal range for this species in spring and summer extends from the Gulf of St. Lawrence/Nova Scotia region

northward (Sergeant 1966; Sutcliffe and Brodie 1977). In fall and winter their precise range is not known, although the population likely moves south into more temperate waters. Blue whales feed entirely on krill, and their summer distribution is determined largely by the distribution of their prey species. There are no verified records from south of Cape Hatteras, North Carolina. Blue whales were for the most part absent from shelf waters; this species generally preferring in deeper slope waters. Only two blue whales (one sighting) were identified off Nova Scotia during the CETAP surveys (CETAP 1982). No blue whales have been sighted in the Gulf of Maine or inside the 200 m contour except for a 1987 sighting of single blue whale along the coast of Massachusetts, in Massachusetts Bay.

#### Sperm Whale

The sperm whale, Physeter macrocephalus, is widely distributed throughout the deep waters of the northern Atlantic between 30°00' and 60°00'N latitudes (Brown 1958). Several discrete stocks have been suggested within this range (Mitchell 1974a). Most of the whales north of 40°00'N latitude are large males that migrate along the continental shelf edge of eastern North America, from Georges Bank along the Scotian Shelf to the Grand Banks, up to Labrador and Hudson Strait, and then offshore into Davis Strait (Katona et al., 1977; Mitchell and Koziki 1984). In the northwest Atlantic, sperm whales were fished commercially off Labrador/Newfoundland (Mitchell 1975b) and Nova Scotia (Mitchell 1975b; Sutcliffe and Brodie 1977). Traditional whaling grounds also occurred southeast of the Grand Banks, off the Carolinas to the southwest Caribbean (Gunter 1954; Leatherwood et al., 1976) and in the Gulf of Mexico (Fritts and Reynolds 1981).

Sperm whales feed primarily on squid (Caldwell et al., 1966; Gambell 1972), mainly deepwater species (Katona et al., 1977). Deep sea fishes and octopus are also taken occasionally (Leatherwood et al., 1976). Within the Gulf of Maine, sperm whales likely feed on the short-finned (Illex illecebrosus) and the long-finned squid (Loligo pealei).

Braham (1984) estimates the North American stock to be 99,500. Estimates of sperm whale abundance within the Gulf of Maine (Scott et al., 1981; CETAP, 1982; MBO, unpublished) are less than 100 individuals. The deeper, central portions of the Gulf of Maine, including Massachusetts Bay and Cape Cod Bay are considered marginal habitat for this species.

The distribution of this species off the east coast of the United States generally is along the shelf-edge and seaward into slope waters in all seasons and generally not in the MBDS study areas.

#### Summary - Cetaceans

In summary, the Gulf of Maine waters are high-use habitat for fin, humpback and right whales between spring and fall. Winter concentrations

of fin and humpback whales are reduced from the other times of the year. Winter distribution and abundance of right whales in the Gulf of Maine are poorly understood.

The southwest Gulf of Maine (Jeffreys Ledge, Stellwagen Bank south along the 100 m contour outside Cape Cod to the Great South Channel) is the subregion of highest use per unit area (greatest density) by large whales between Cape Hatteras, North Carolina and Nova Scotia. The endangered whale species, noted in this report, use this area throughout the year, with densest concentrations occurring spring through fall.

The easternmost 10' latitudinal block in this study (Figure 3.C.5-1) encompasses the northwest corner of Stellwagen Bank. Kenney (1985) found this area to be in the highest habitat-use category for cetaceans between Cape Hatteras, North Carolina and Nova Scotia. The middle 10' quadrat also is an area of high cetacean use with a habitat-use index > 90-95th percentile. It is in this 10' square that MBDS is located, with the actual 2 nautical mile diameter site having an aerial coverage of approximately 5% of the total.

#### MARINE TURTLES

Until recently, the distributions of marine turtles off the northeastern United States were known primarily from strandings and reports of opportunistic sightings at sea (Babcock, 1919; Bleakney, 1965; Lazell, 1976). The first comprehensive study of the spatial and temporal distribution and abundance of sea turtles in this area was conducted by CETAP (Shoop *et al.*, 1981). There are four members of the family Cheloniidae present in the study area: loggerhead turtle (Caretta caretta), Atlantic Rيدleys turtle (Lepidochelys kempi), hawksbill turtle (Eretmochelys imbricata), and green turtle (Chelonia mydas). The leatherback turtle (Dermochelys coriacea); (Family: Dermochelyidae) is a fifth turtle species found in our study area. Predation on eggs and hatchlings, human disturbance on nesting beaches (McFarlane 1963), excessive demand for turtle products, trawl entanglement, and consumption by local fishermen are all reasons for their current threatened or endangered status (Nat'l. Fish and Wildl. Laboratory 1980a, 1980b, 1980c, 1980d).

Marine turtles feed at several trophic levels from herbivore to tertiary carnivores. With the exception of D. coriacea, marine turtles feed mostly on the bottom and forage close to shores and reefs, generally in waters less than 60 m deep (Shoop *et al.* 1981). C. mydas is mostly herbivorous, feeding on marine algae and marine grasses (Carr 1952, Nat'l. Fish and Wildl. Laboratory 1980a). L. kempi, E. imbricata, and C. caretta are omnivorous and feed on a wide variety of invertebrates, algae and fish (Nat'l. Fish and Wildl. Laboratory 1980b). The diet of the Atlantic Rيدleys turtle consists mostly of crabs Arenaeus sp., Callinectes sp., Calappa sp., and Hepatus sp. (Nat'l. Fish and Wildl. Laboratory 1980c). Leatherback turtles are open water or pelagic carnivores feeding

principally on jellyfish (Carr 1952, Nat'l Fish and Wildl. Laboratory 1980d) and favor Cyanea sp. in the Gulf of Maine (Lazell 1976). In the study area, turtles have been shown to forage on the green crab (Carcinus maenas) and the blue mussel (Mytilus edulis) (Sam Sadove, OKEANOS FOUNDATION. pers. comm.).

#### Loggerhead Turtle

The loggerhead turtle (Caretta caretta), a threatened species, is the most widespread and numerous sea turtle along the eastern seaboard (CETAP, 1982; Payne and Ross, 1986). Its range during the winter and early spring is south of 37°00'N latitude in estuarine rivers, coastal bays and shelf waters of the southeastern United States (see Figure 3.C.5-8). Their distribution is the most restricted during the winter months (sightings generally occur south of Cape Hatteras), prior to spring and early summer nesting. Their distribution is most widespread in summer and fall coinciding with a northward dispersal phase which follows the peak nesting period, at this time sightings occur throughout shelf waters north to Massachusetts. Their offshore distribution (beyond the edge of the continental shelf) in summer also extends north along the eastern United States to approximately 42°00'N latitude.

Loggerheads are generally absent in shelf waters north of Cape Cod, including Cape Cod Bay and the Gulf of Maine. Prolonged exposure to water temperatures lower than 10-15°C may cause dormancy, cold-stunning or death. The northward dispersal following nesting results in limited sightings along outer Cape Cod and the islands mid-summer through fall. Sporadically loggerheads become trapped inside Cape Cod Bay in late-fall and winter, resulting in cold-stunning and death. Generally, Massachusetts is at the northern range limit for this species, therefore these waters are considered marginal habitat (Payne and Ross, 1986).

#### Atlantic Ridleys Turtle

The Ridleys sea turtle (Lepidochelys kempi), an endangered species has the most restricted breeding range of any sea turtle, nesting within a few hundred miles of Rancho Nuevo on the southern coast of Tamaulipas, Mexico (National Fish and Wildlife Lab. 1980c). Their adult life is spent in the Gulf of Mexico; however, as juveniles they appear as far north as New England either by actively swimming or drifting in the Gulf Stream (Lazell, 1976; Shoop, 1980; Prescott, 1986). Juvenile Ridleys which turn up in Massachusetts are generally 10" to 12" long and weigh up to seven pounds (Prescott 1986). Waters off southern New England are important feeding areas for Ridleys turtles and are considered important habitat for this species (Lazell, 1980). Each fall as water temperature drop in Cape Cod Bay between 12 and 30 immature Ridleys strand on Cape Cod (Prescott, 1986). This species may transit the MBDS study area, but it generally follows offshore patterns.

## Green Turtle

Green turtles (Chelonia mydas), an endangered species, are found worldwide in waters warmer than 20°C, although juveniles sometimes are found in cooler waters (Nat'l. Fish and Wildlife Laboratory 1980a). Green turtles are rare summer stragglers as far north as Cape Cod Bay (CETAP, 1982; Shoop and Ruckdeschel, 1986a). Individuals in Massachusetts waters are usually juvenile and probably from the endangered Florida breeding population. Gulf of Maine sightings are extremely rare (CETAP 1982).

## Hawksbill Turtle

The Hawksbill turtle Eretmochelys imbricata, an endangered species, is scattered throughout the world's tropical oceans, though it is infrequently observed north of Florida on the Atlantic coast. A single juvenile carapace, presumably from somewhere on Cape Cod, is the only museum record of this species for New England (Shoop and Ruckdeschel 1986b). They are considered absent from Gulf of Maine waters, including Cape Cod Bay.

## Leatherback Turtle

The leatherback turtle (Dermochelys coriacea), an endangered species, is the largest and most distinctive of the sea turtles. It is widespread in the oceans of the world (Nat'l Fish and Wildlife Laboratory 1980d). Leatherbacks nest on tropical beaches, after which, the adults move into temperate waters to feed. This is the second most common turtle along the eastern seaboard of the United States (Fig 3.C.5-9), and the most common north of 42°00'N latitude (Gulf of Maine, including Georges Bank and Cape Cod Bay).

The leatherback is a strongly pelagic species. The large flippers and streamlined body allow prolonged, fast swimming. Their large body size and a special arrangement of blood vessels in the skin and flippers enable them to retain heat generated during swimming. Leatherbacks maintain body temperatures several degrees above the temperature of the surrounding water, facilitating their travel to cool temperate waters where food is abundant. However, their physiological adaptations to pelagic life make leatherbacks poorly suited to deal with obstructions in shallow waters. They regularly become entangled in fishing nets and lobster pot lines. Leatherbacks possess a limited ability to maneuver and cannot swim backward to disentangle themselves. Leatherbacks are reported to have died of intestinal blockage after eating floating plastic bags, which they presumably mistake for jellyfish, their desired prey. They are also occasionally killed by collisions with boats.

Adults migrate extensively throughout the Atlantic basin. There are numerous records of leatherbacks in New England and as far north as Nova Scotia and Newfoundland (Ross, 1986). Sightings off Massachusetts are most common in the late summer months (July - September) (Shoop et. al.



1981; CETAP, 1982), and the leatherbacks seen here are usually of adult sizes. The leatherback's seasonal migration is the reverse of that of the Loggerhead. Leatherback turtles move northward beyond the shelf-break, possibly to within the Gulf Stream; therefore there are few sightings in the spring months (CETAP, 1982). They first appear in the Gulf of Maine (north of 42°00'N latitude) in late May to June, and from 42°00'N to approximately 38°00'N in shelf waters from June through October (Shoop et al. 1981). Sightings of leatherbacks peak during the summer, most in the southern New England coastal regions (CETAP 1982). They are not seen above Cape Hatteras in winter.

#### Summary - Marine Turtles

The five species of marine turtles that potentially would occur in the study area includes the loggerhead turtle (Caretta caretta), Atlantic Ridley's turtle (Lepidochelys kempi), hawksbill turtle (Eretmochelys imbricata), green turtle (Chelonia mydas), and the leatherback turtle (Dermochelys imbricata). Of these, Massachusetts Bay is considered marginal habitat for loggerhead and Atlantic Ridley's turtles, green turtles, and hawksbill turtles are rare or absent from Massachusetts Bay. The leatherback turtle would be the only species expected to occur in the study area, seasonally in late spring through summer, feeding opportunistically of jellyfish in the water column.

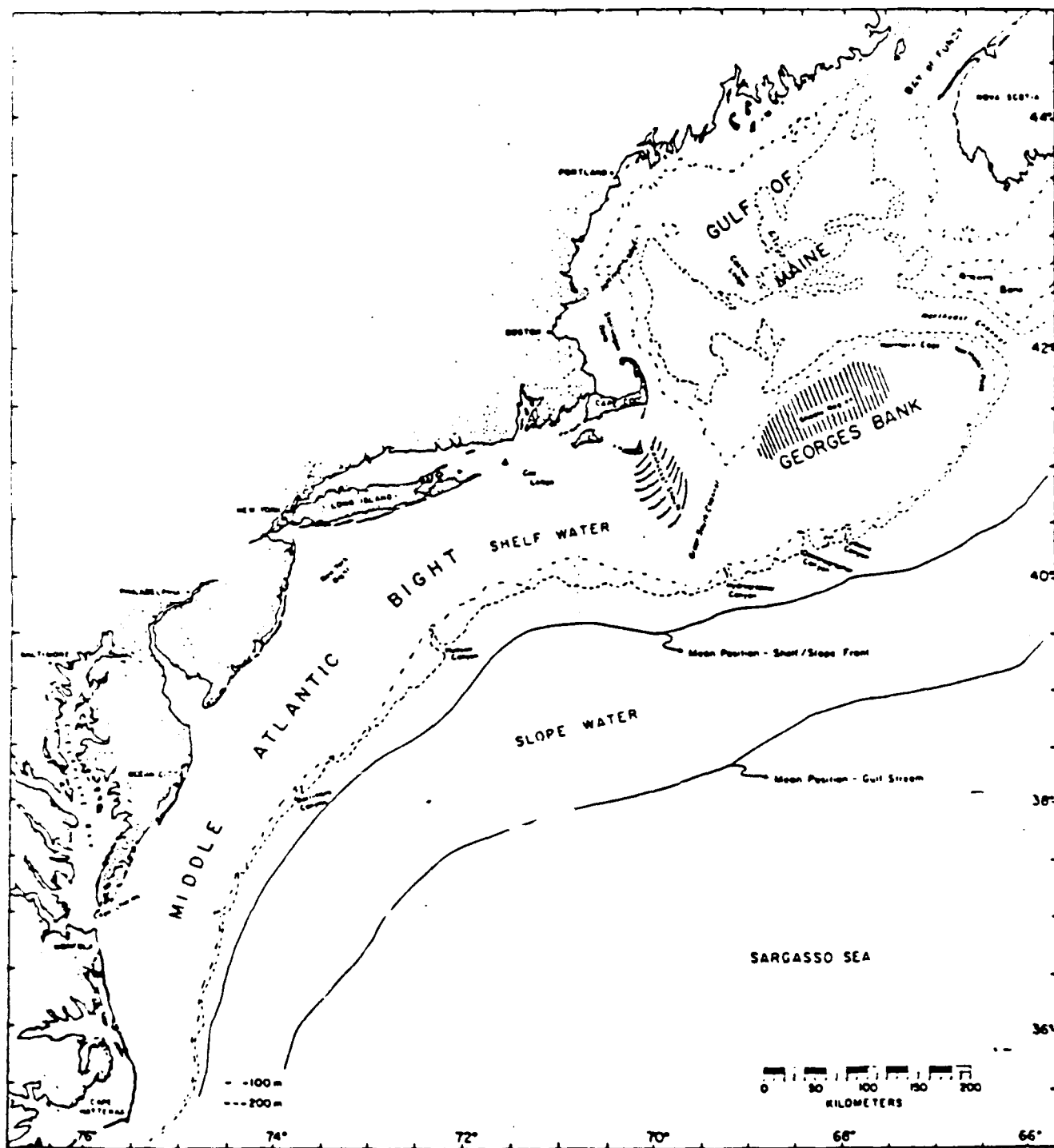


Figure 3.C.5-1: Bathymetry and principal features of the continental shelf and slope off the northeastern United States.

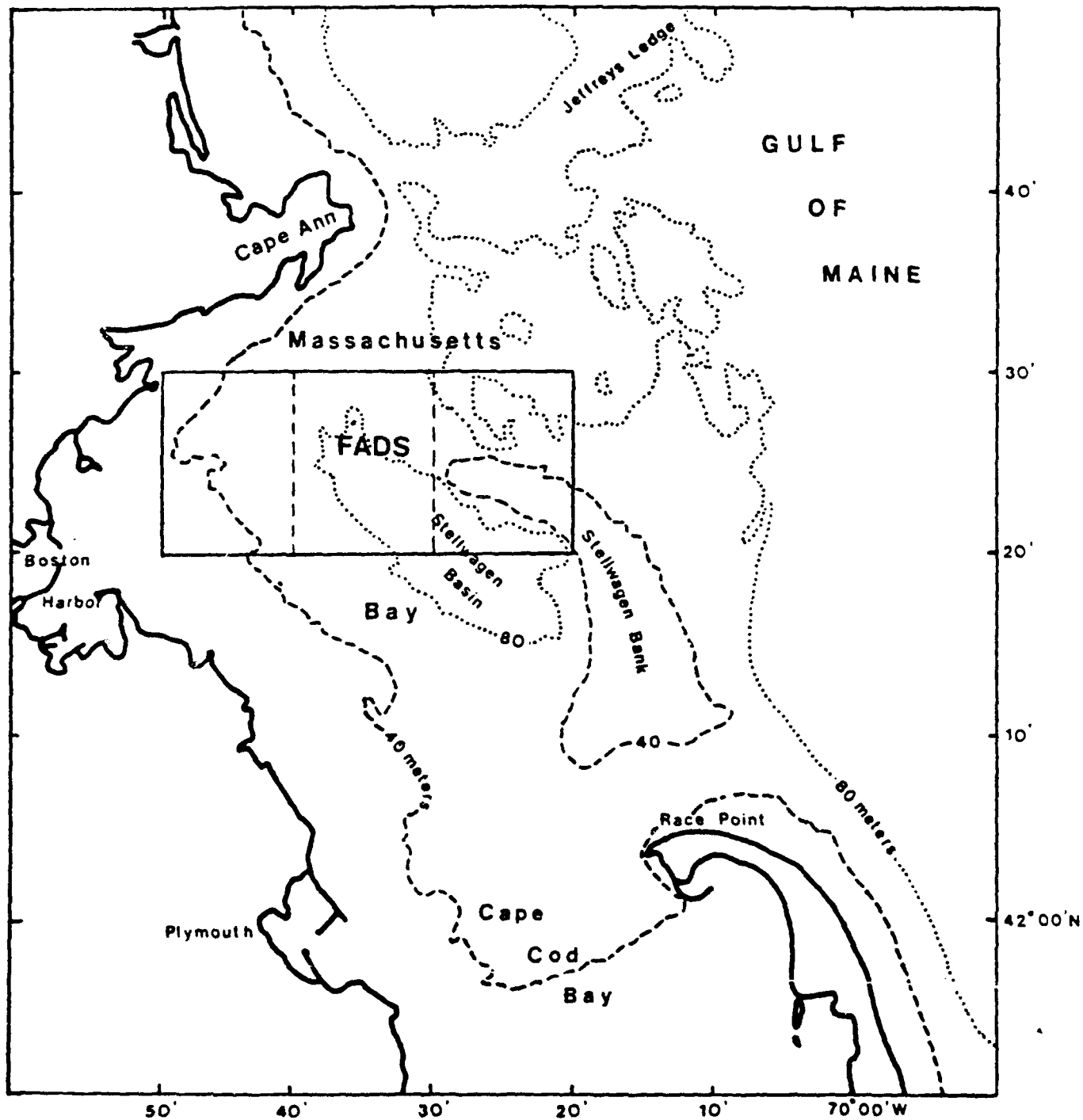


Figure 3.C.5-2: The location of the Mass Bay Disposal Site (MBDS) relative to Massachusetts Bay and Cape Cod Bay.

Figure 3.C.5-3a: Relative distribution and abundance of humpback whales in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.

Relative Abundance  
cetaceans per 10'x10' block

- 1 - 9
- 10 - 99
- >100

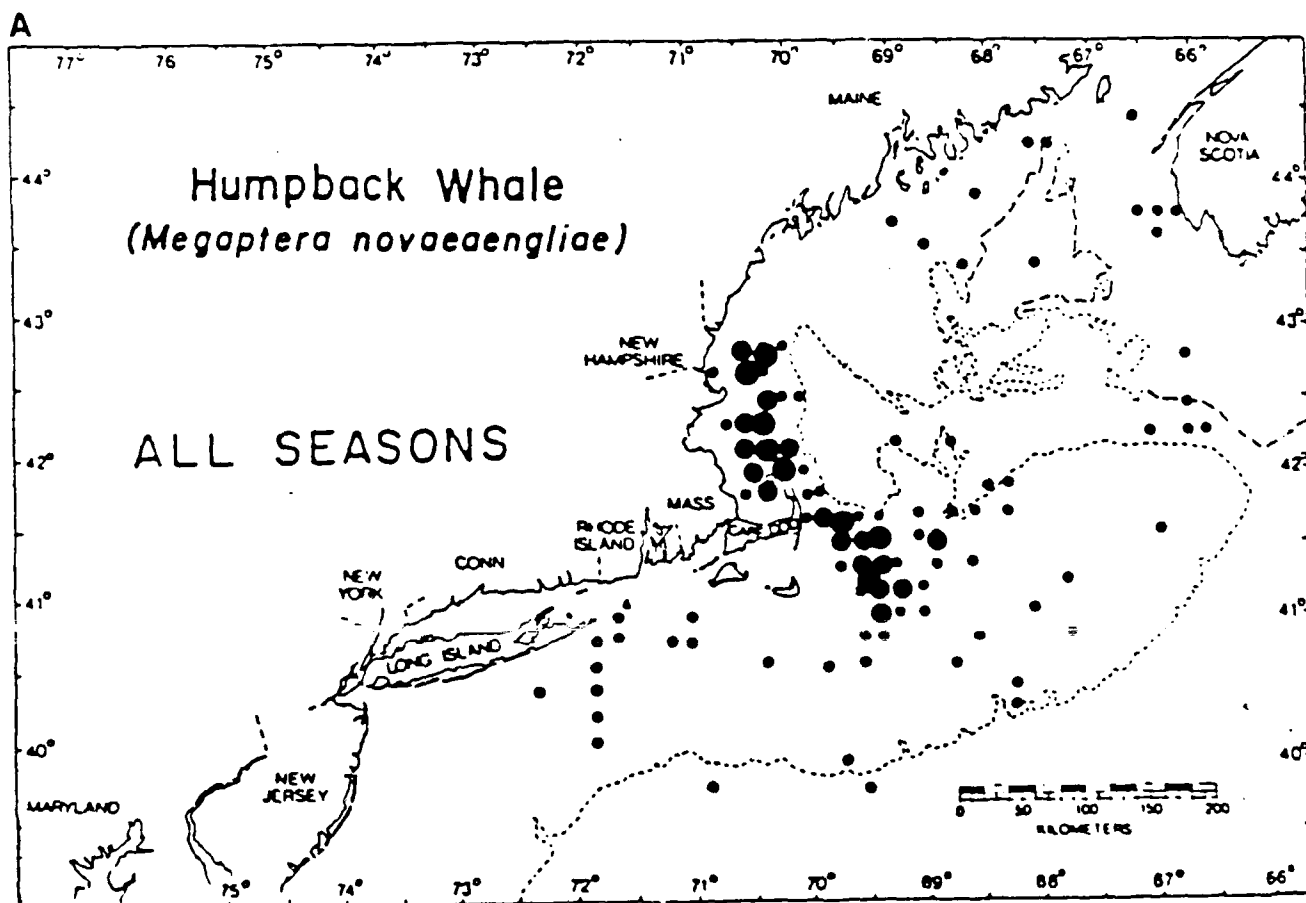
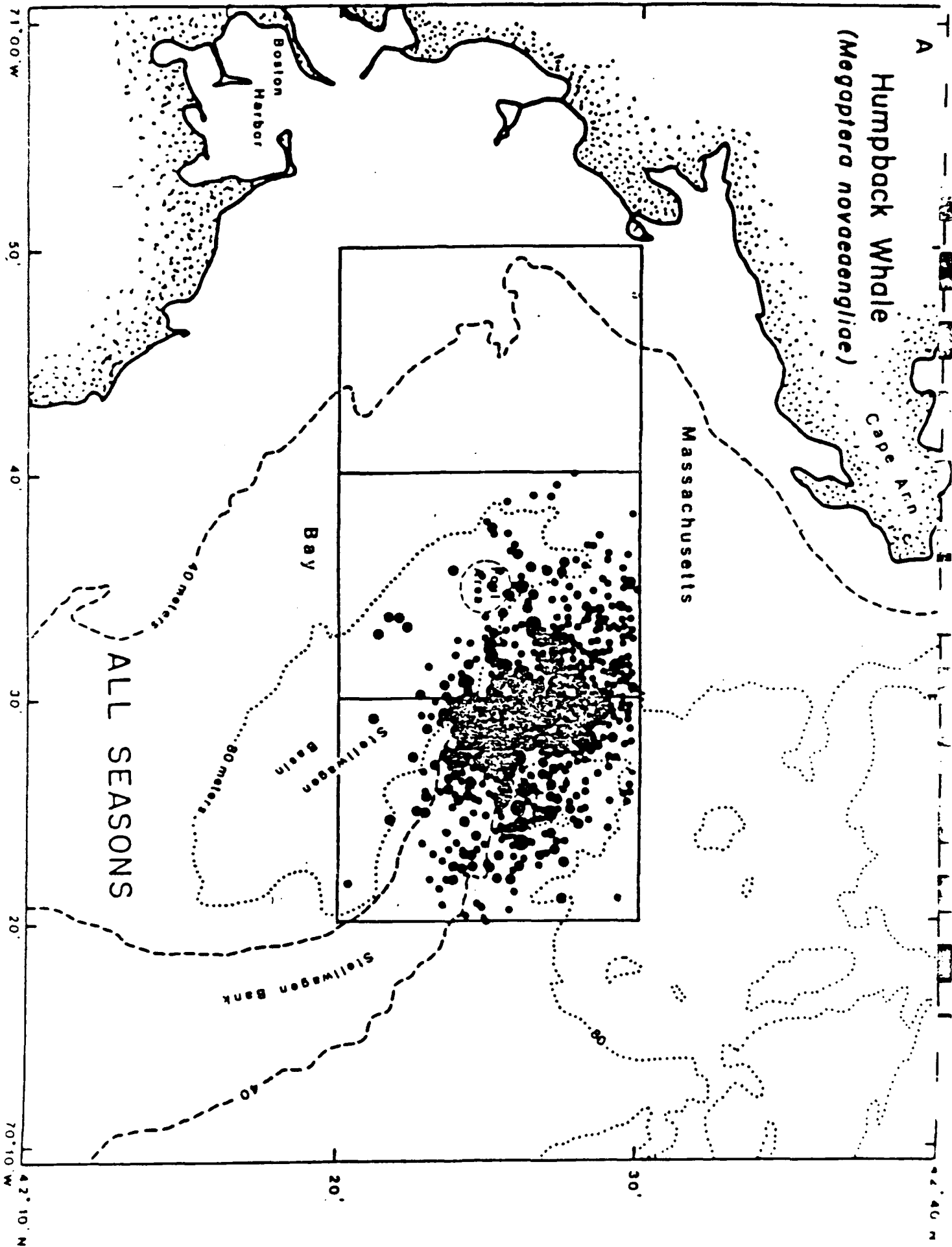


Figure 3.C.5- Sightings of the humpback whale within the waters of the Mass. Bay  
3b through f Disposal Site study area by season.

Sources: Data from the Cetacean Research Unit; Hain et al. 1981;  
Payne et al. 1984; MBO unpubl. data, 1985-1986; Gulf of  
Maine Cetacean Sighting Network 1975-1981, and from aerial  
surveys during this study.



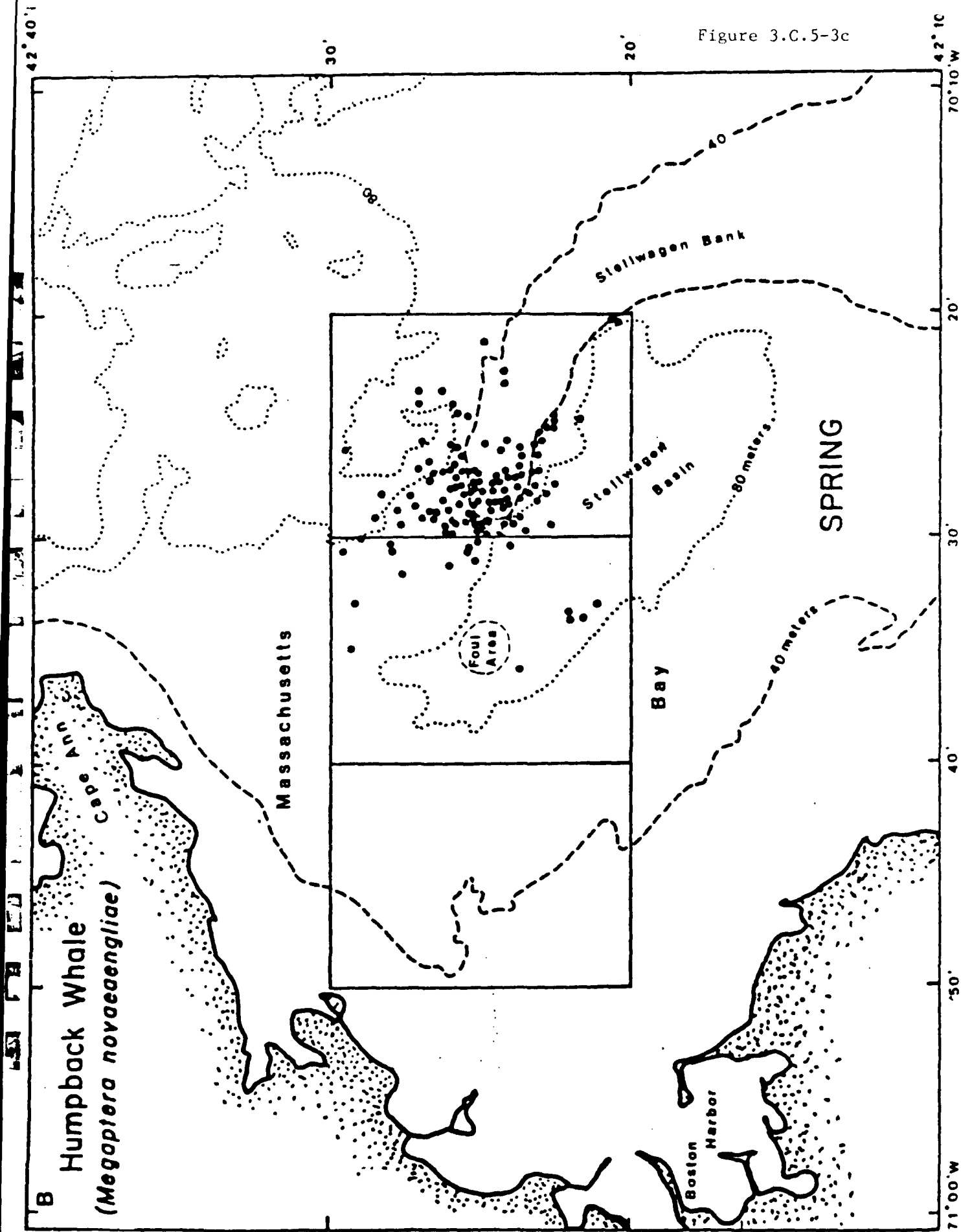
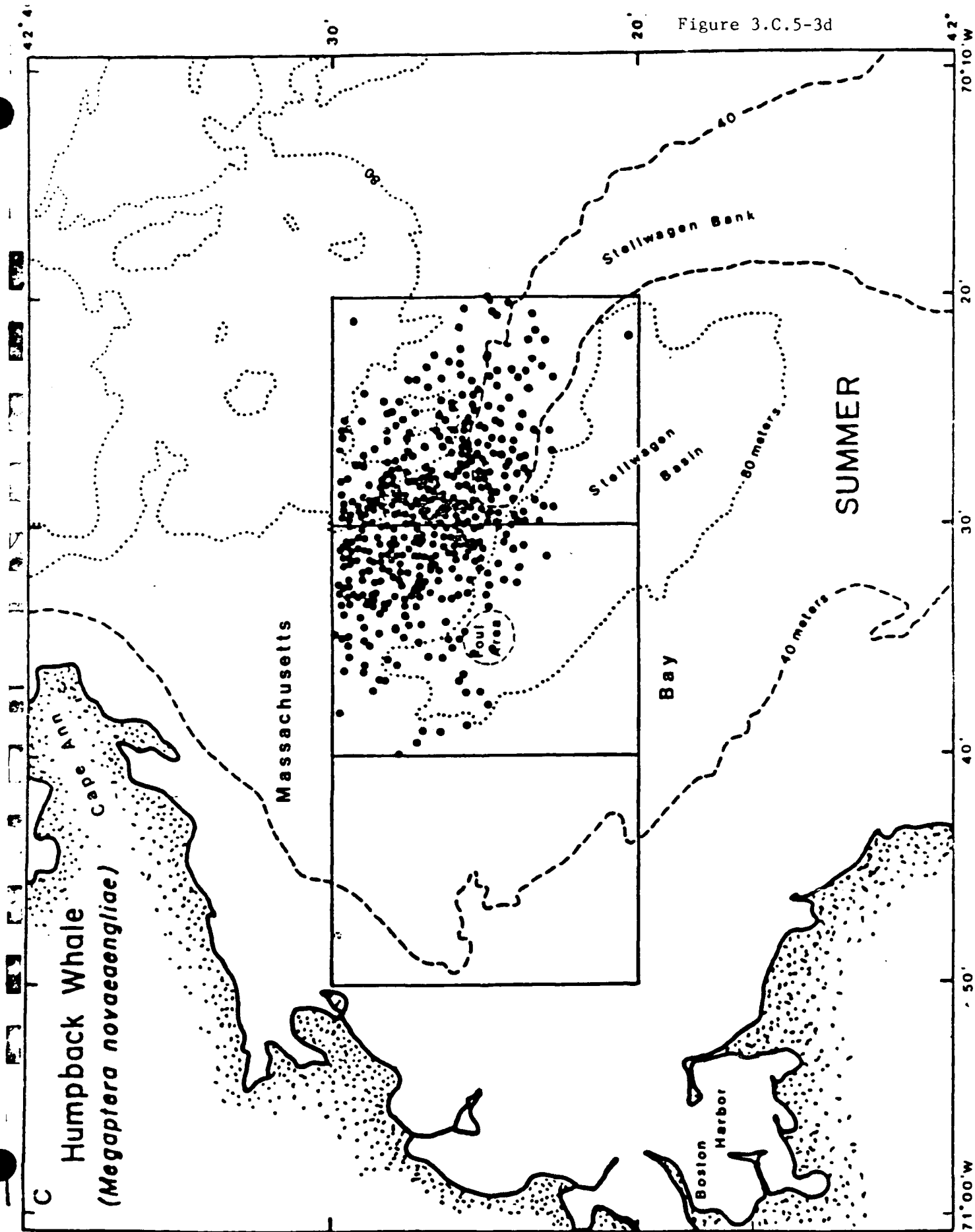


Figure 3.C.5-3d





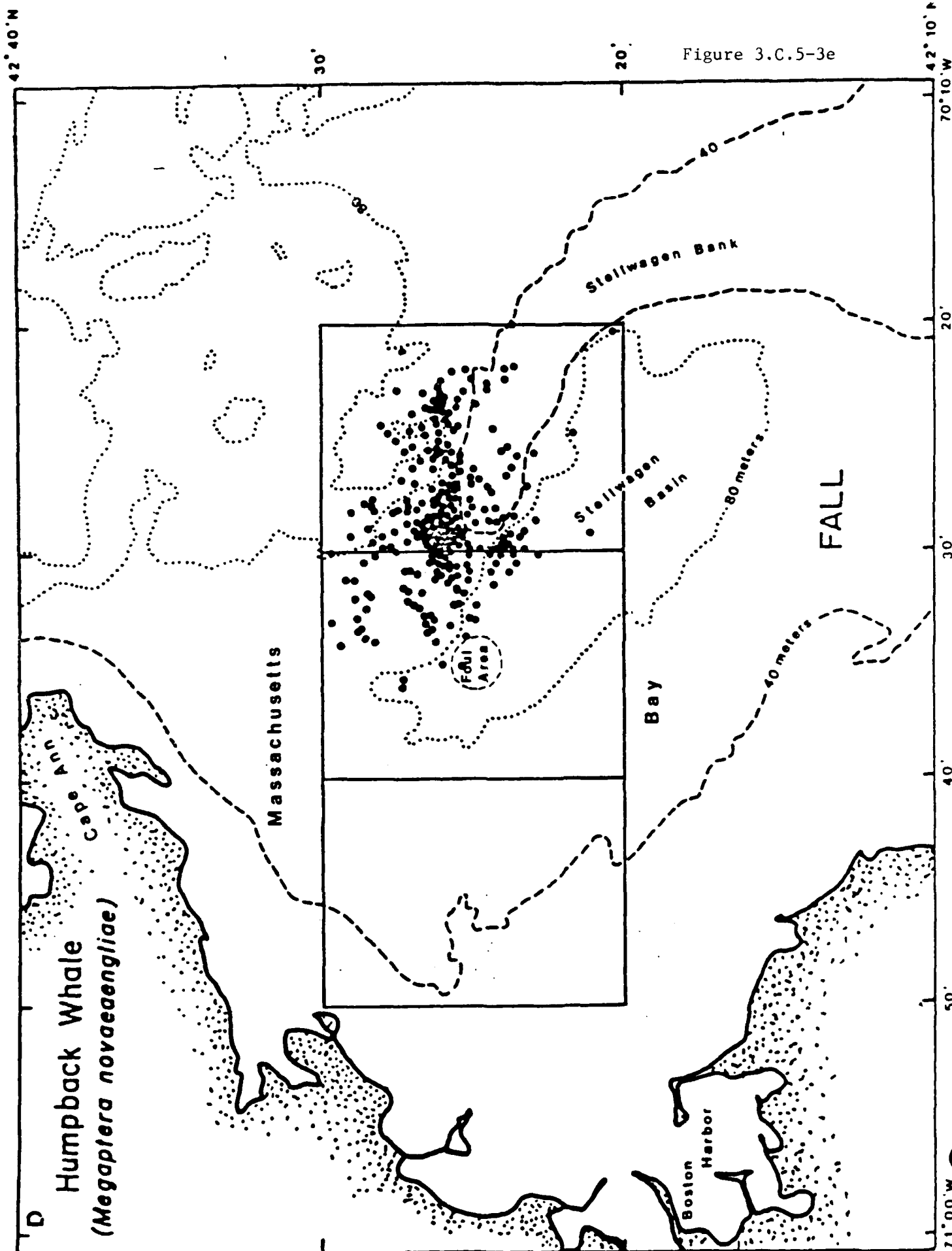


Figure 3.C.5-3f

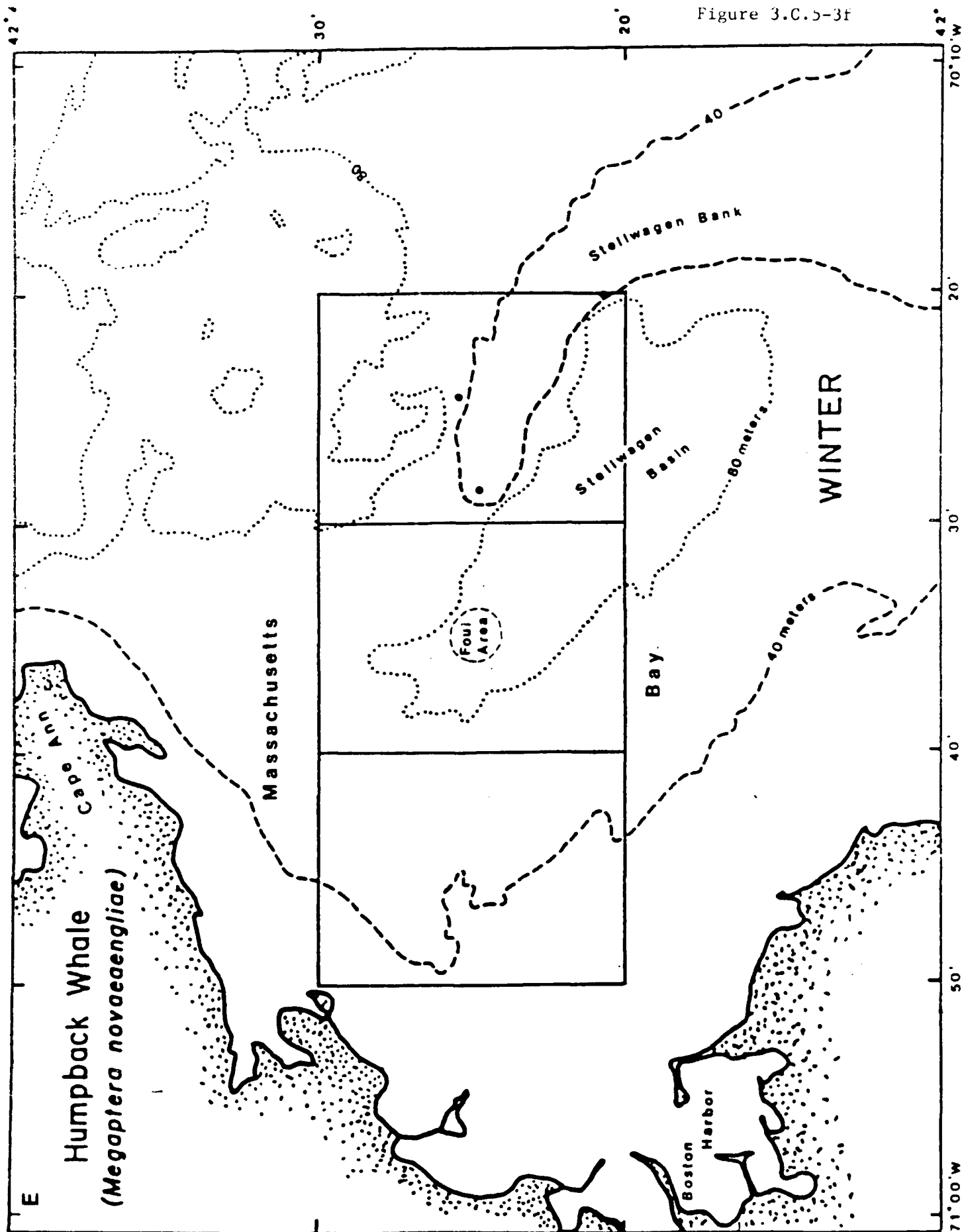


Figure 3.C.5-4 Sightings of surface-feeding by humpback whales within the waters of the Mass. Bay Disposal Site study area for all seasons.

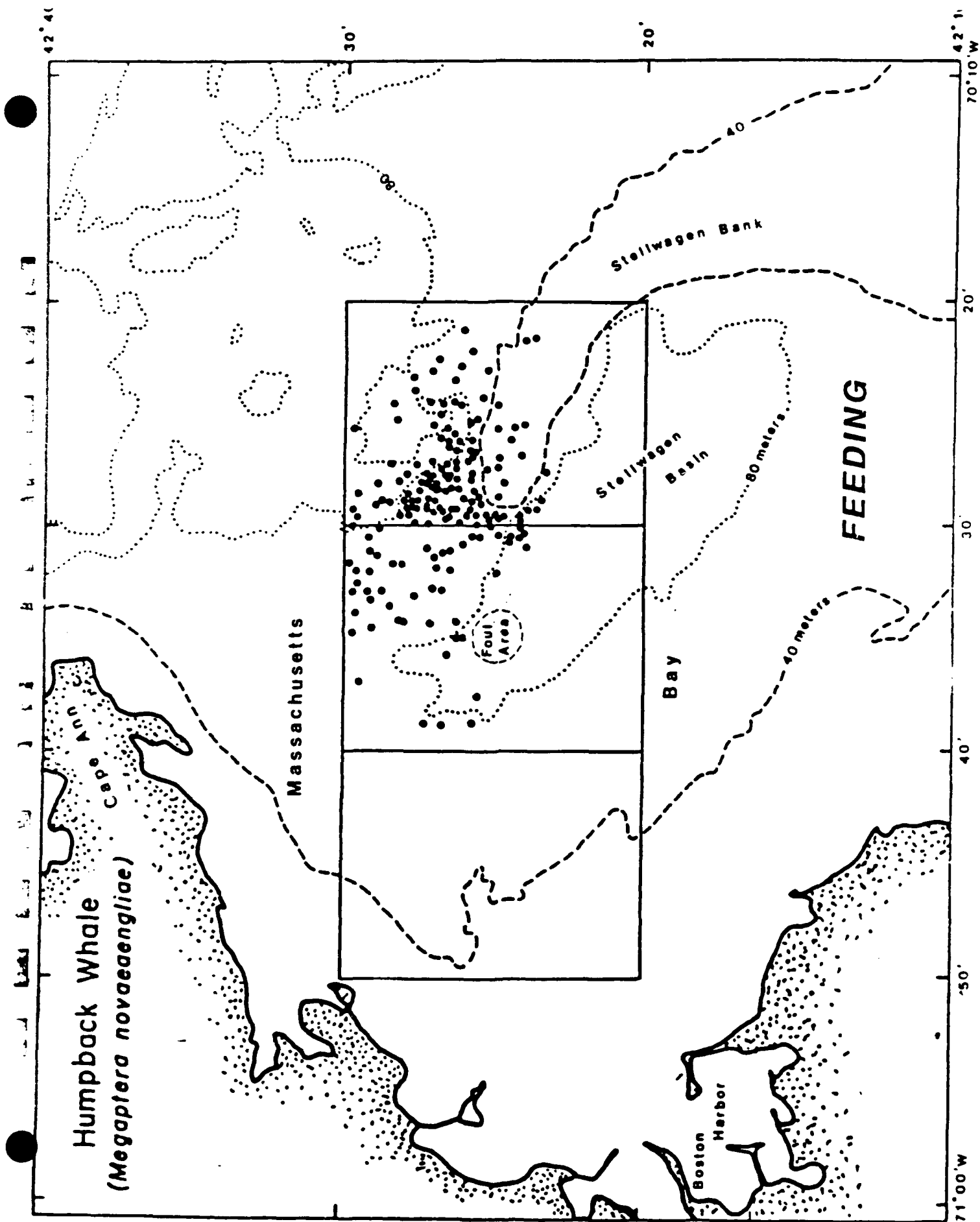


Figure 3.C.5-5 Sightings of humpback whales with calves within the waters of the  
Mass. Bay Disposal Site study area for all seasons.

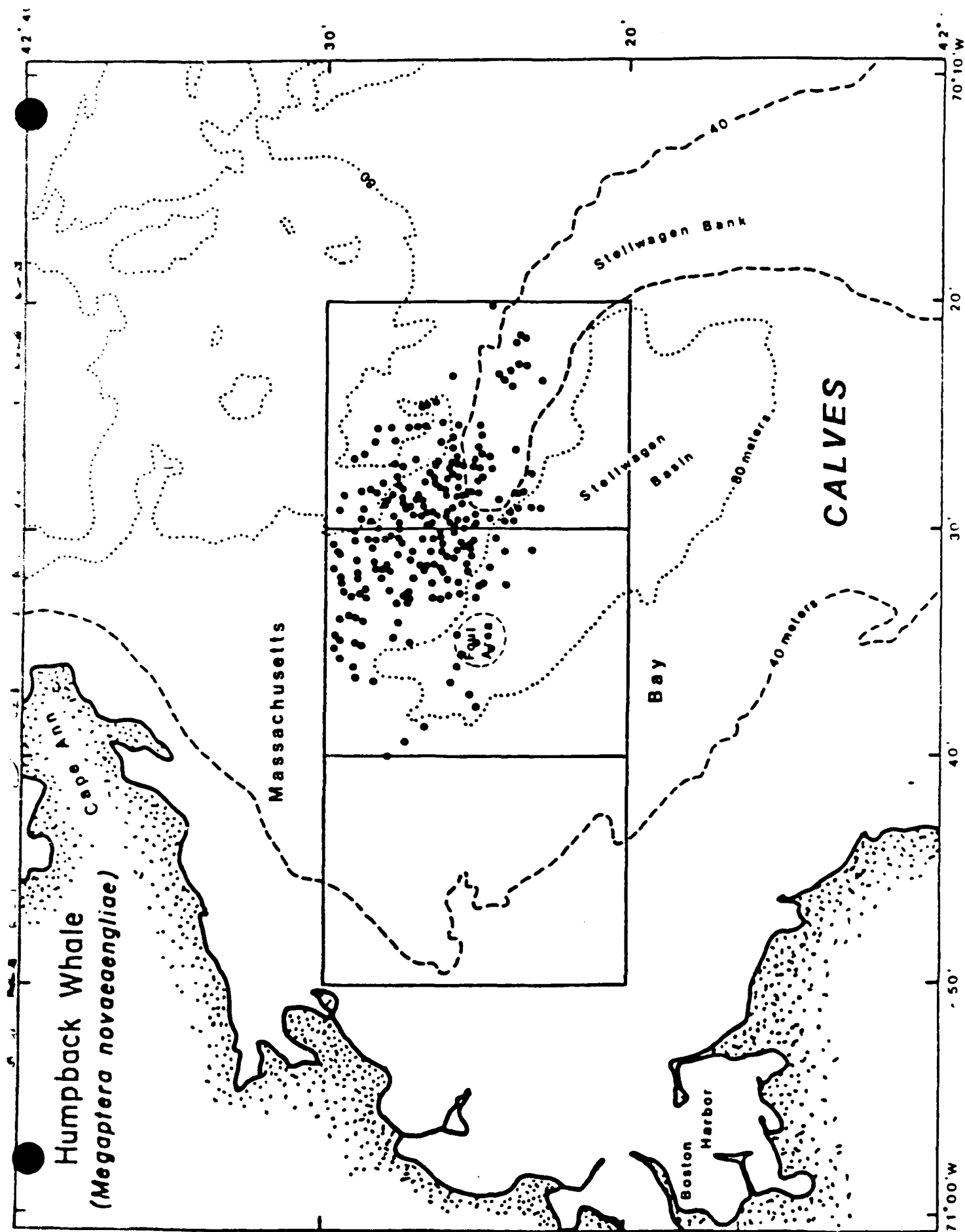
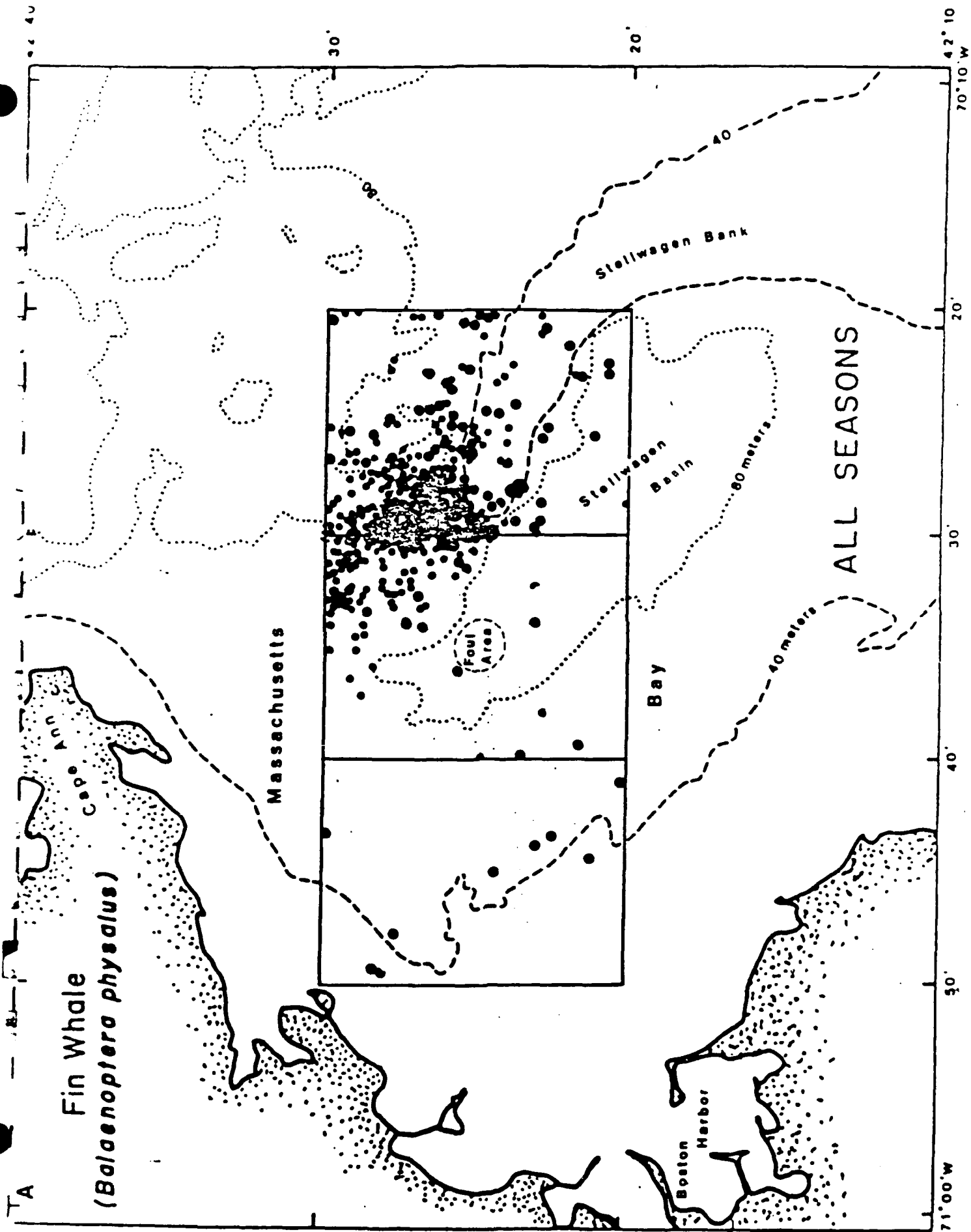


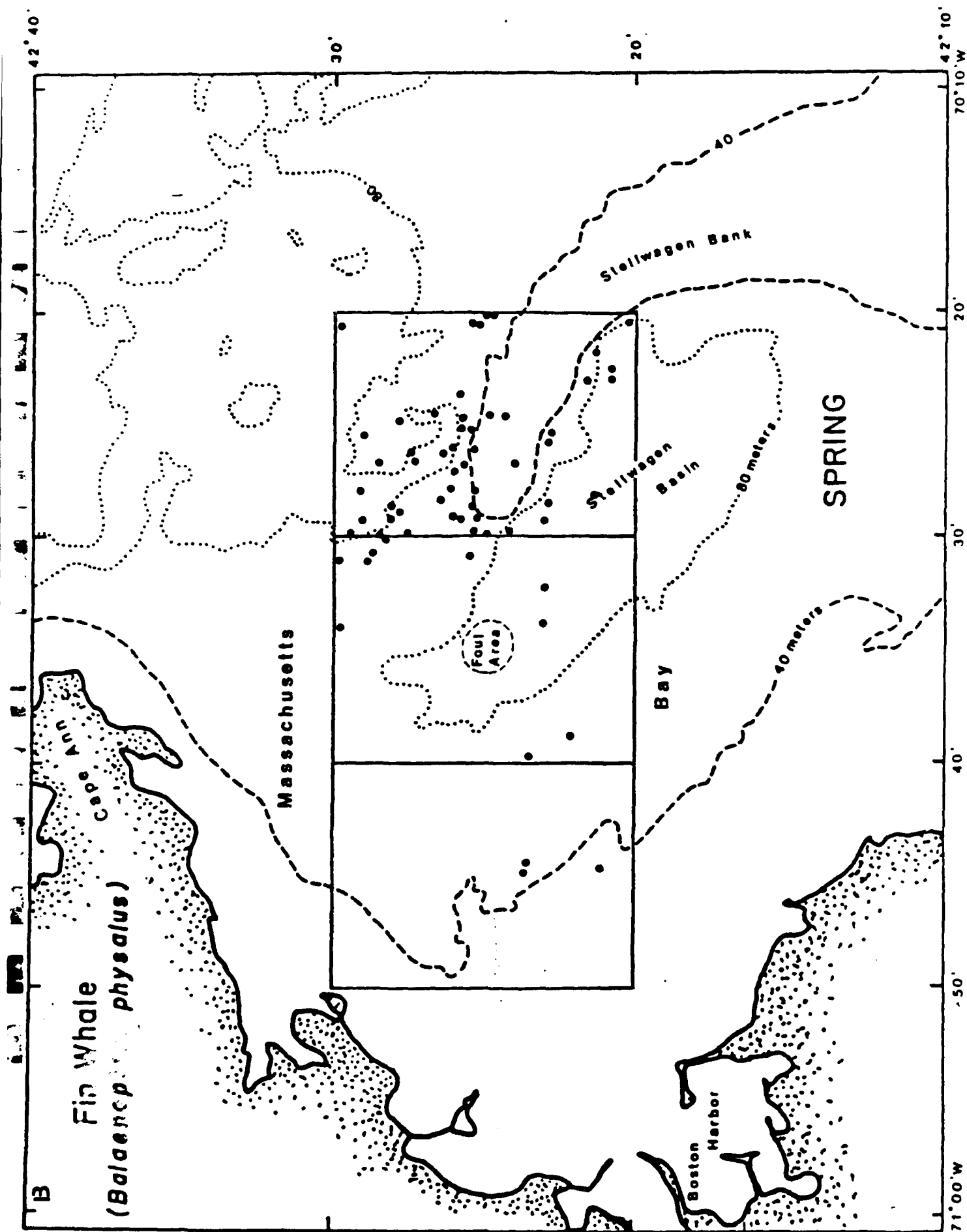
Figure 3.C.5-  
6a through e

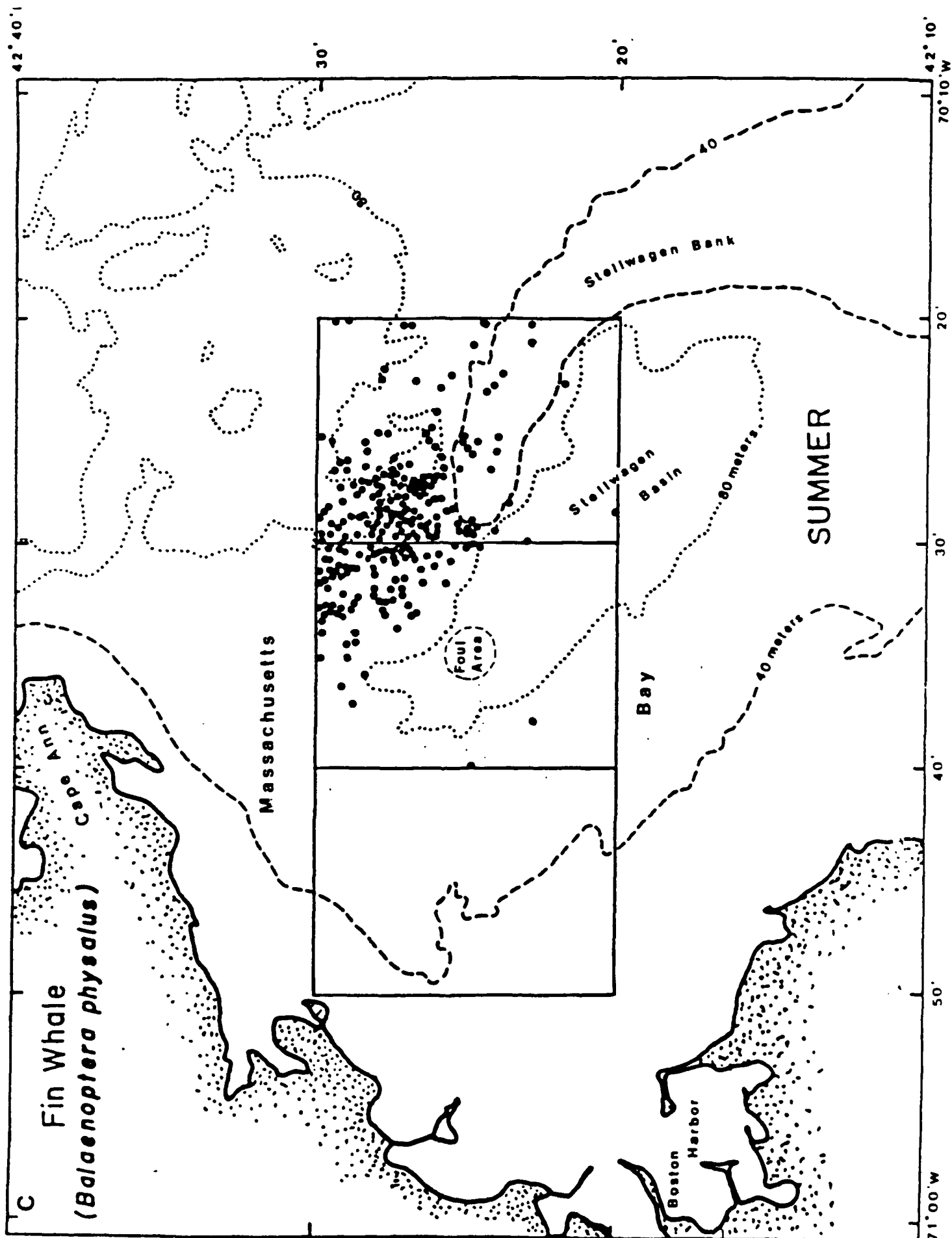
Sightings of fin whales within the waters of the Massachusetts  
Bay study area by season.

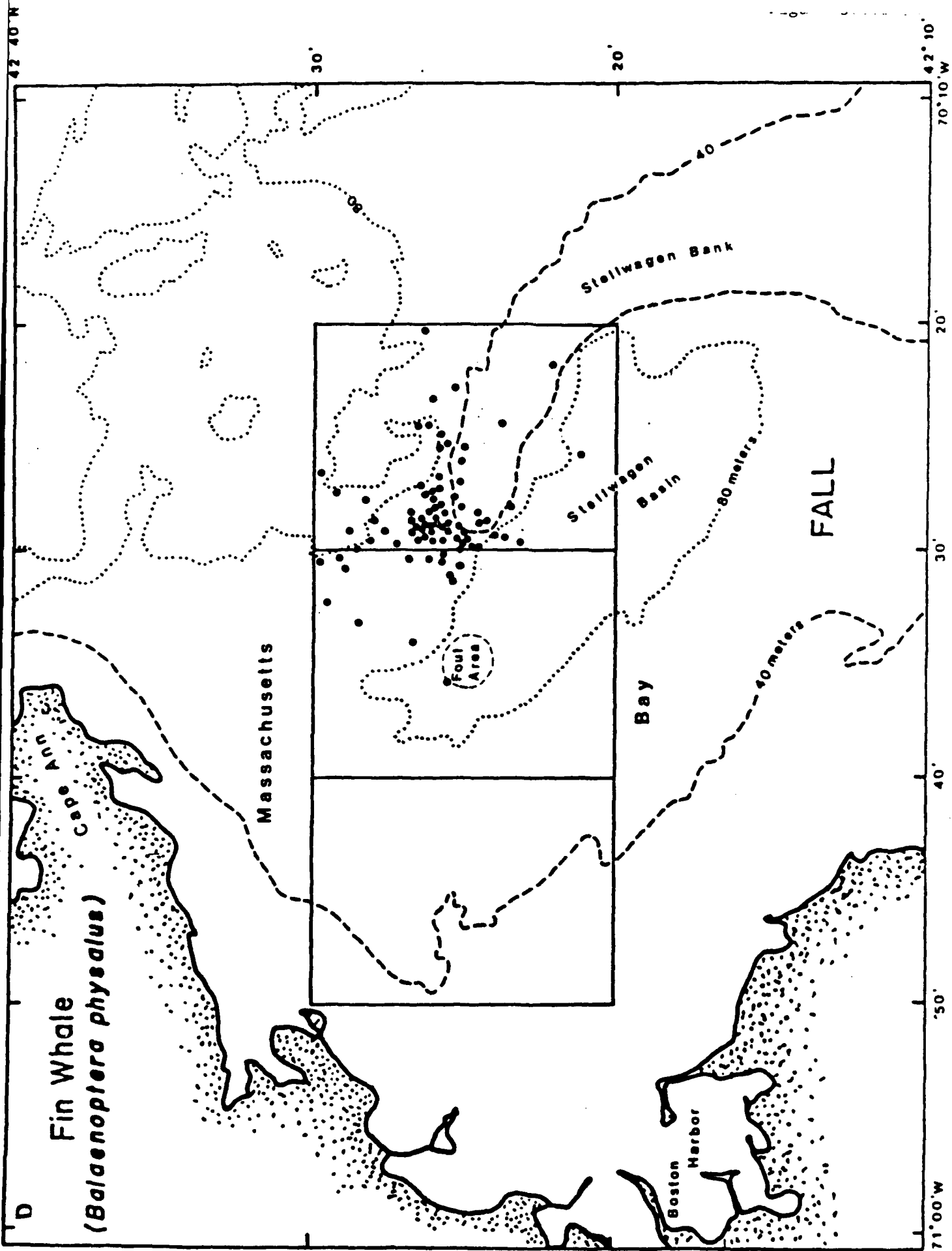
Sources: Data from the Cetacean Research Unit; Hain et al. 1981;  
Payne et al. 1984; MBO unpubl. data, 1985-1986; Gulf of  
Maine Cetacean Sighting Network 1975-1981; and from  
aerial surveys during this study.











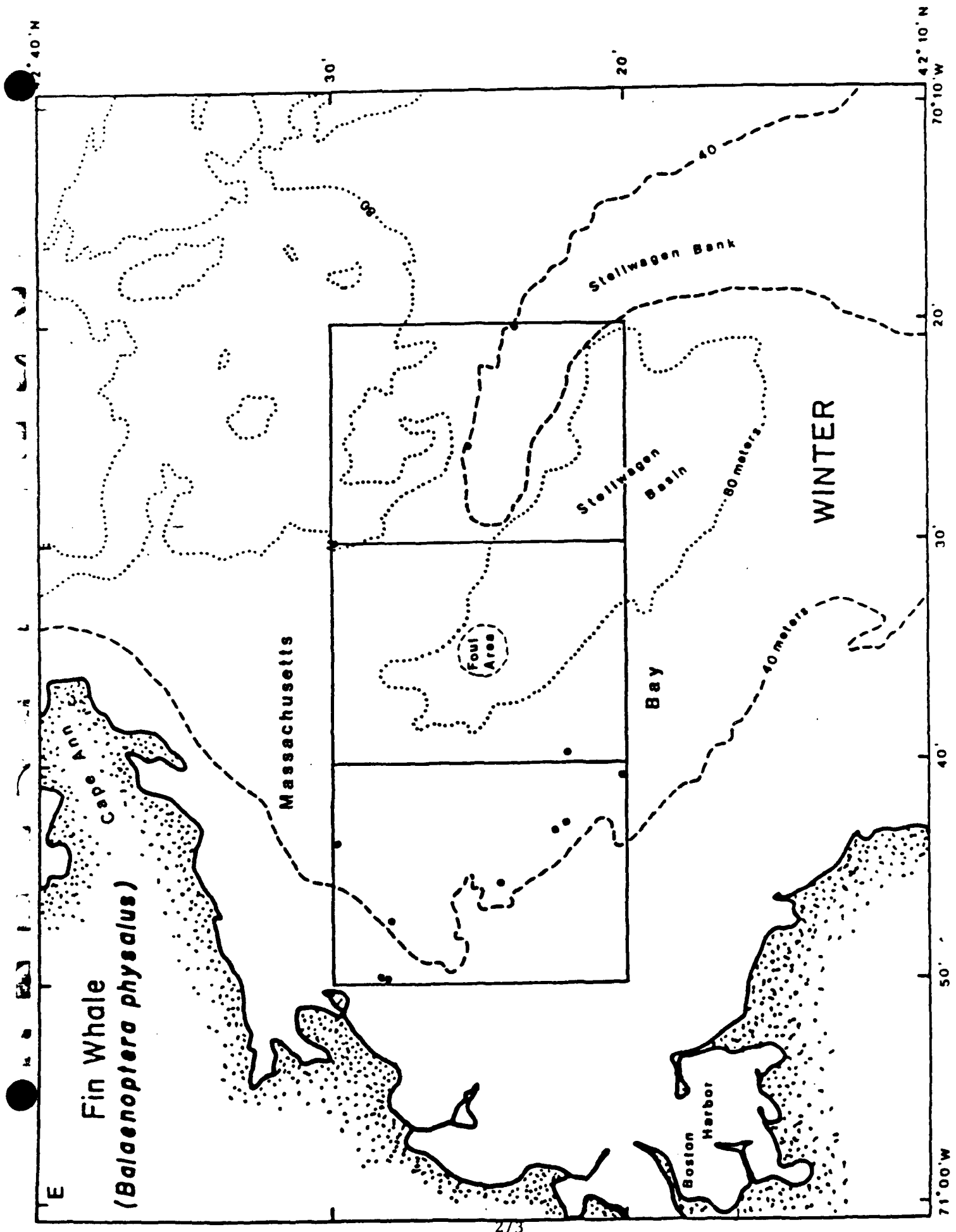


Figure 3.C.5-7 Relative distribution and abundance of right whales in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) by season.

Relative Abundance  
cetaceans per 10'x10' block

- 1 - 9
- 10 - 99
- >100

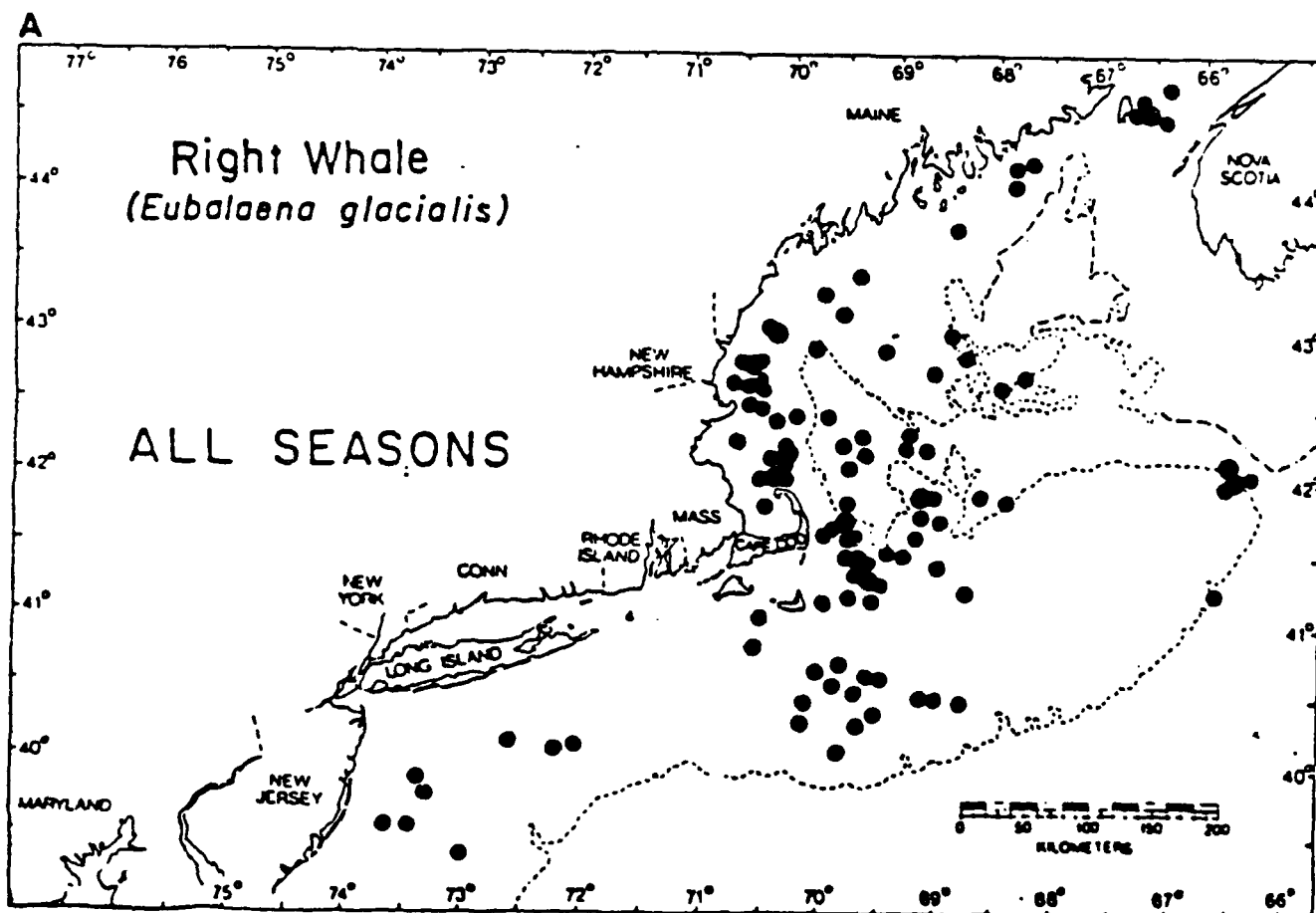


Figure 3.C.5-8 Relative distribution and abundance of loggerhead turtles in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) for all seasons.

Relative Abundance  
cetaceans per 10'x10' block

- 1 - 9
- 10 - 99
- >100

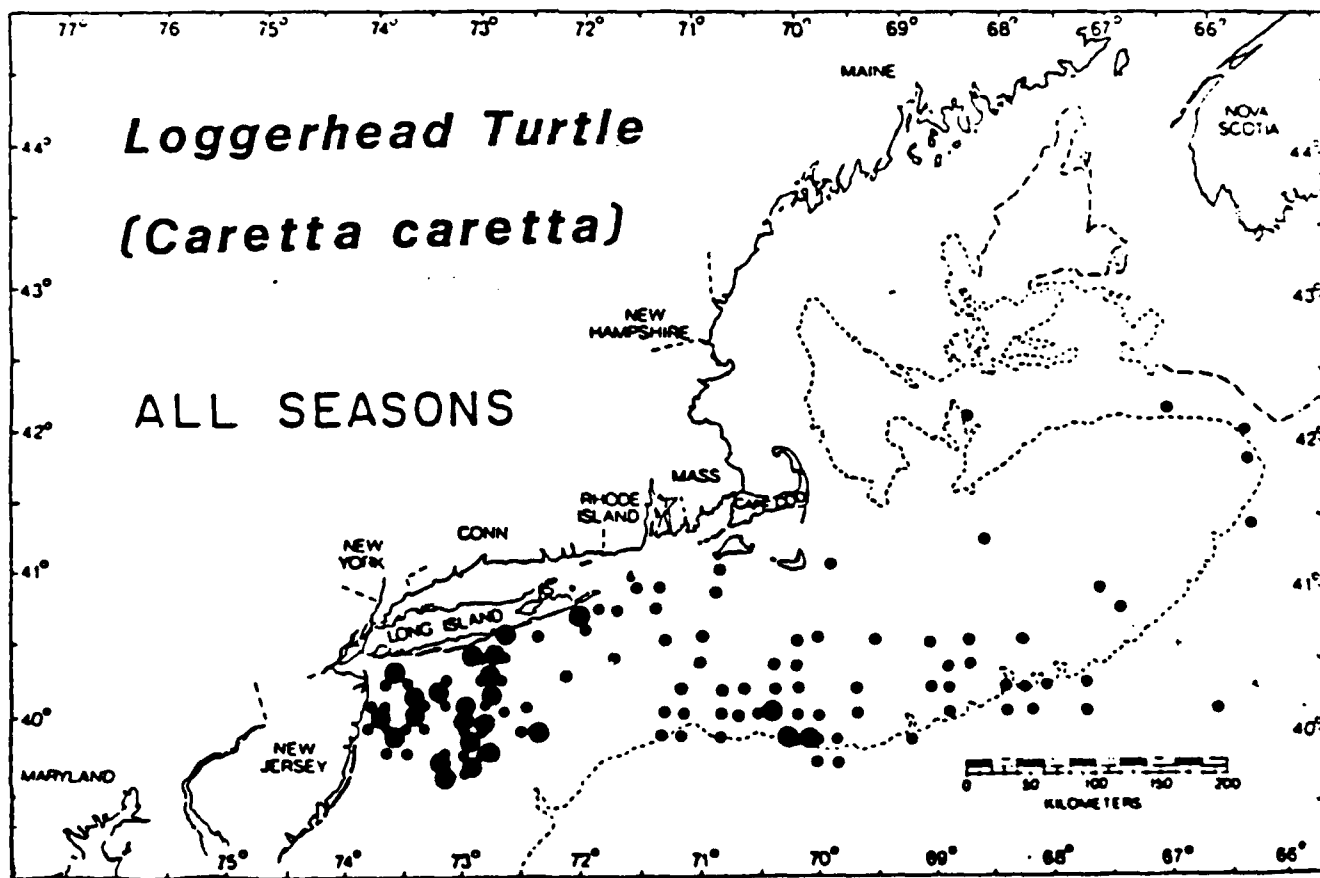


Figure 3.C.5-9 Relative distribution and abundance of leatherback turtles in the Gulf of Maine, including Georges Bank (north of 40°00'N latitude) for all seasons.

Relative Abundance  
cetaceans per 10'x10' block

- 1 - 9
- 10 - 99
- >100

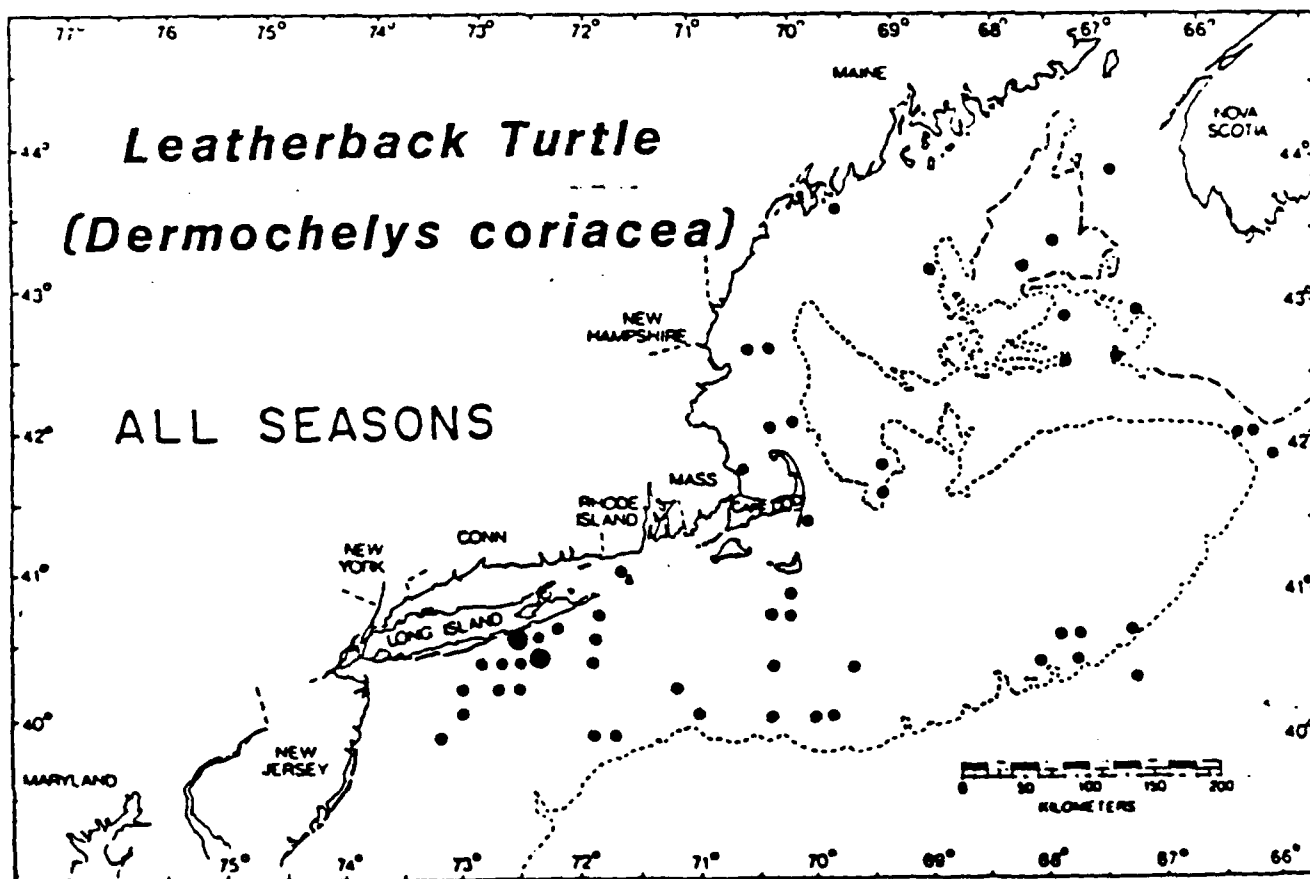


Table 3.C.5-1. List of whales, dolphins and porpoises (order Cetacea) which commonly occur in the waters of the Gulf of Maine, including Georges Bank.

Suborder Mysticeti (Baleen Whales)

Family Balaenopteridae

|                |                               |            |
|----------------|-------------------------------|------------|
| Finback Whale  | <u>Balaenoptera physalus</u>  | Endangered |
| Minke Whale    | <u>B. acutorostrata</u>       | Endangered |
| Sei Whale      | <u>B. borealis</u>            | Endangered |
| Humpback Whale | <u>Megaptera novaeangliae</u> | Endangered |

Family Balaenidae

|                      |                            |            |
|----------------------|----------------------------|------------|
| Northern Right Whale | <u>Eubalaena glacialis</u> | Endangered |
|----------------------|----------------------------|------------|

Suborder Odontoceti (Toothed Whales)

Family Phocoenidae

|                 |                          |
|-----------------|--------------------------|
| Harbor Porpoise | <u>Phocoena phocoena</u> |
|-----------------|--------------------------|

Family Delphinidae

|                           |                                     |
|---------------------------|-------------------------------------|
| Bottlenosed Dolphin       | <u>Tursiops truncatus</u>           |
| Spotted Dolphin           | <u>Stenella plagiodon/attenuata</u> |
| Striped Dolphin           | <u>S. coerueoalba</u>               |
| Common Dolphin            | <u>Delphinus delphis</u>            |
| White-sided Dolphin       | <u>Lagenorgynchus acutus</u>        |
| White-beaked Dolphin      | <u>L. albirostris</u>               |
| Grampus (Rissa's Dolphin) | <u>Grampus griseus</u>              |
| Long-finned Pilot Whale   | <u>Globicephala melaena</u>         |
| Killer Whale              | <u>Orcinus orca</u>                 |

Family Physeteridae

|             |                               |            |
|-------------|-------------------------------|------------|
| Sperm Whale | <u>Physeter macrocephalus</u> | Endangered |
|-------------|-------------------------------|------------|

Source: Hain et al. 1981; CETAP 1982; Katona et al. 1983; Payne et al. 1984.



Table 3.C.5-2. List of whales, dolphins and porpoises (Order Cetacea) which occur uncommonly (from sight records or strandings) in waters of the Gulf of Maine, including Georges Bank.

Suborder Mysticeti (Baleen Whales)

Family Balaenopteridae

|            |                              |            |
|------------|------------------------------|------------|
| Blue Whale | <u>Balaenoptera musculus</u> | Endangered |
|------------|------------------------------|------------|

Suborder Odontoceti (Toothed Whales)

Family Delphinidae

Family Monodontidae

|        |                              |
|--------|------------------------------|
| Beluga | <u>Delphinapterus leucas</u> |
|--------|------------------------------|

Family Physeteridae

|                   |                        |
|-------------------|------------------------|
| Pygmy Sperm Whale | <u>Kogia breviceps</u> |
|-------------------|------------------------|

Family Ziphiidae

|                            |                                |
|----------------------------|--------------------------------|
| Northern Bottlenosed Whale | <u>Hyperoodon ampullatus</u>   |
| Dense-beaked Whale         | <u>Mesoplodon densirostris</u> |
| True's Beaked Whale        | <u>M. mirus</u>                |
| North Sea Beaked Whale     | <u>M. bidens</u>               |

Source: Katona et al. 1983

Table 3.C.5-3. List of rare (r), seasonal (s), and commonly (c) occurring marine turtles (Order Testudines) in the waters of the Gulf of Maine, including Georges Bank.

Family Cheloniidae

|                      |                               |                |
|----------------------|-------------------------------|----------------|
| Loggerhead Turtle    | <u>Caretta caretta</u>        | Threatened (r) |
| Green Turtle         | <u>Chelonia mydas</u>         | Endangered (r) |
| Kemp's Ridley Turtle | <u>Lepidochelys kemp</u>      | Endangered (r) |
| Hawksbill Turtle     | <u>Eretmochelys imbricata</u> | Endangered (r) |

Family Dermochelyidae

|                    |                             |                |
|--------------------|-----------------------------|----------------|
| Leatherback Turtle | <u>Dermochelys coriacea</u> | Endangered (s) |
|--------------------|-----------------------------|----------------|

Source: French (1986)

Table 3.C.5-4. List of rare (r) and commonly (c) occurring pinnipeds in coastal waters of the Gulf of Maine.

Family Phocidae (True or Hair Seals)

|             |                                 |     |
|-------------|---------------------------------|-----|
| Harbor Seal | <u>Phoca vitulina concolor</u>  | (c) |
| Ringed Seal | <u>P. hispida</u>               | (r) |
| Gray Seal   | <u>Halichoerus grypus</u>       | (c) |
| Harp Seal   | <u>Pagophilus groenlandicus</u> | (r) |
| Hooded Seal | <u>Cystophora cristata</u>      | (r) |

Family Odobenidae

|                 |                                   |                |
|-----------------|-----------------------------------|----------------|
| Atlantic Walrus | <u>Odobenus rosmarus rosmarus</u> | fossil records |
|-----------------|-----------------------------------|----------------|

Source: Katona et al. 1983

### 3.D. Commercial and Recreational Characteristics

#### 3.D.1. FISHING INDUSTRY

Nationally, fisheries statistics are generated by point of catch and grouped in ten minute squares which are assigned to statistical areas. The Massachusetts Bay Disposal Site is located in statistical "area 514" (Figure 3.D.1-1). It is estimated that approximately 100 commercial fishing vessels fish in area 514. Interviews were conducted with fishermen in Gloucester, Cohasset, and Scituate during the summer of 1985. Commercial fishing in the area consists of draggers, gill netters, and lobster boats. Each of these techniques are discussed below.

##### Dragging

Draggers from different ports fish on smooth bottom in the general vicinity of the disposal site at various times during the course of the calendar year. These include vessels from: Salem, (2); Lynn, (2); Nahant, (1); Boston, (5 to 6), Scituate, (12); Gloucester, (20); Green Harbor, (2); and Plymouth, (6); (total 51). From the interviews it was determined that while most of these draggers stay away from the disposal site, some boats from Gloucester and Scituate fish on the southwestern and southeastern portions of MBDS.

The fish caught by draggers usually consist of flounder and American Plaice. These species are harvested throughout the year. This type of catch is usually found on the flounder ground, a flat bottom section of the ocean floor where trawlers can operate without fear of damaging their equipment. In addition, redfish and wolffish are caught near patches of hard bottom. Other species important to the fishing industry are winter flounder and yellowtail flounder. Although these species are not caught in great numbers in MBDS, they are harvested in other areas near the disposal site. In the winter, lobster and cod are important by-catch for draggers.

According to the NMFS, a large amount of fish landed by New England draggers is caught in statistical area 514. For this area, the percentage of American Plaice caught was 14.6% of the total catch of this species off the Northeastern coast of the United States. Area 514 represented 7.9% of the winter flounder, 3.4% of the yellowtail flounder, and 12% of the witch flounder caught off the northeastern United States. Although a substantial percentage of the species caught by draggers are found in area 514, most are not caught in the vicinity of the Massachusetts Bay Disposal Site.

##### Gill netting

Gill netters set their gear from 10 to 20 miles offshore. Very few full-time gill netters fish in the MBDS. Cod is the main target species for gillnetters who fish off the coast of Massachusetts. In the

spring and winter, most gill nets are set shoreward in areas where the sea floor is rough in order to avoid the operations of draggers which may damage their nets. In addition, State laws keep draggers out of areas used by gillnetters.

Gillnetters from ports north and south of Boston, have occasionally set their nets within MBDS. Based on an interview, one fisherman stated that the catch size for cod was, on occasion, large but there was no concentration of fish in the site. In an unrelated interview another fisherman reported that he no longer fishes in the Massachusetts Bay Disposal Site after his gear was contaminated by black, foul-smelling mud.

### Lobstering

Lobster boats change their catch locations in accordance with seasonal lobster migrations. In the winter, lobsters move to deeper waters in search of warmer water and to avoid storms. In summer months, lobsters migrate toward shallow water and as a result lobster boats move inshore to increase their catch sizes. The table below provides an estimate of the number of lobster boats fishing in the vicinity of MBDS:

NUMBER OF LOBSTER BOATS FISHING  
IN GENERAL VICINITY OF MBDS  
(BASED ON 1985 SURVEY  
INTERVIEWS)

| <u>VESSEL PORT</u> | <u>NUMBER</u> |
|--------------------|---------------|
| GLOUCESTER         | 12            |
| BEVERLY            | 5-6           |
| MARBLEHEAD         | 4             |
| SWAMPSCOTT         | 2-3           |
| NAHANT             | 1             |
| LYNN               | 1             |
| BOSTON             | 4-5           |
| WEYMOUTH           | 2             |
| COHASSET           | 10            |
| SCITUATE           | 2             |
| SAUGUS             | 1-2           |
| HULL               | 2             |

Only one lobsterman stated that he had fished in MBDS. He reported that the lobsters there were all legal size and appeared to be of high quality. On one occasion he reported that his pots were fouled with black mud, 300 feet north of the "A" buoy. Some areas of the disposal site were reported absent of lobsters because disposal activities have taken place there from time to time. In general, lobster boats avoid the area.

### FISHING UTILIZATION

The catch for area 514 in 1984 is presented in Table 3.D.1-1. In total, this area accounts for approximately 5.7 percent of all the landings off the northeastern United States. In 1984, this area was the source of approximately 84.3 percent of the dogfish, 27 percent of the sea herring, 32 percent of the red hake, and nearly 21 percent of the silver hake off the northeastern United States.

The total U.S. landings in this area (514) increased from 88,681,543 pounds in 1974 to 123,972,150 pounds in 1984, an increase of approximately 28 percent. The increase may be due primarily to the exclusion in 1977 of foreign fishing vessels from waters within 200 miles of the coastline. Landings and value data for the period 1972 to 1974 are reported in Appendix III data for the period 1982 to 1984 are also reported in Appendix III.

Data were also available from the NMFS on the area immediately surrounding the Massachusetts Bay Disposal Site. The summary tables that evaluate each of the species and value per pounds caught per year is given in Appendix III. The NMFS was able to break down catch sized for three ten minute squares within the statistical area. The three 10 minute squares immediately surrounding MBDS area 514 are described below:

#### LATITUDE

42°25'  
42°25'  
42°25'

#### LONGITUDE

70°25'  
70°35'  
70°45'

In 1984, the total number of pounds landed for all species in area 514 was 123,972,150 which was valued at \$18,840,350. For the three 10 minute squares (study area) considered for the Massachusetts Bay Disposal Site, the total number of pounds landed was 41,937,628 which was valued at \$2,461,806.75. These quantities comprise approximately 33.8 percent of the landings from area 514 and 13% of the value of the catch in this area.

### LANDINGS VALUE FOR MBDS

Using the data compiled in the Appendix tables, estimates were made as to the total value of the fishing landings in the Massachusetts Bay Disposal Site. This was done by totaling the number of pounds landed (and its value) for each species in the area longitude 42°25' and latitude 70°35'. The landings and values were collected and averaged for three years - 1982, 1983, and 1984. This mean value for three years was then multiplied by 6%, MBDS percentage of the total area of longitude 42°25' and latitude 70°35'. Using this methodology, a maximum potential catch value for all species in the Massachusetts Bay Disposal Site was estimated to be \$21,320 per year. This would represent an upward

limit on the value of MBDS. It assumes uniform fishing effort over the entire 10 minute square which, from evidence presented above, is not likely. Cod, flounder, and American plaice were the most economically important species caught in area 514 and the three ten minute squares surrounding MBDS.

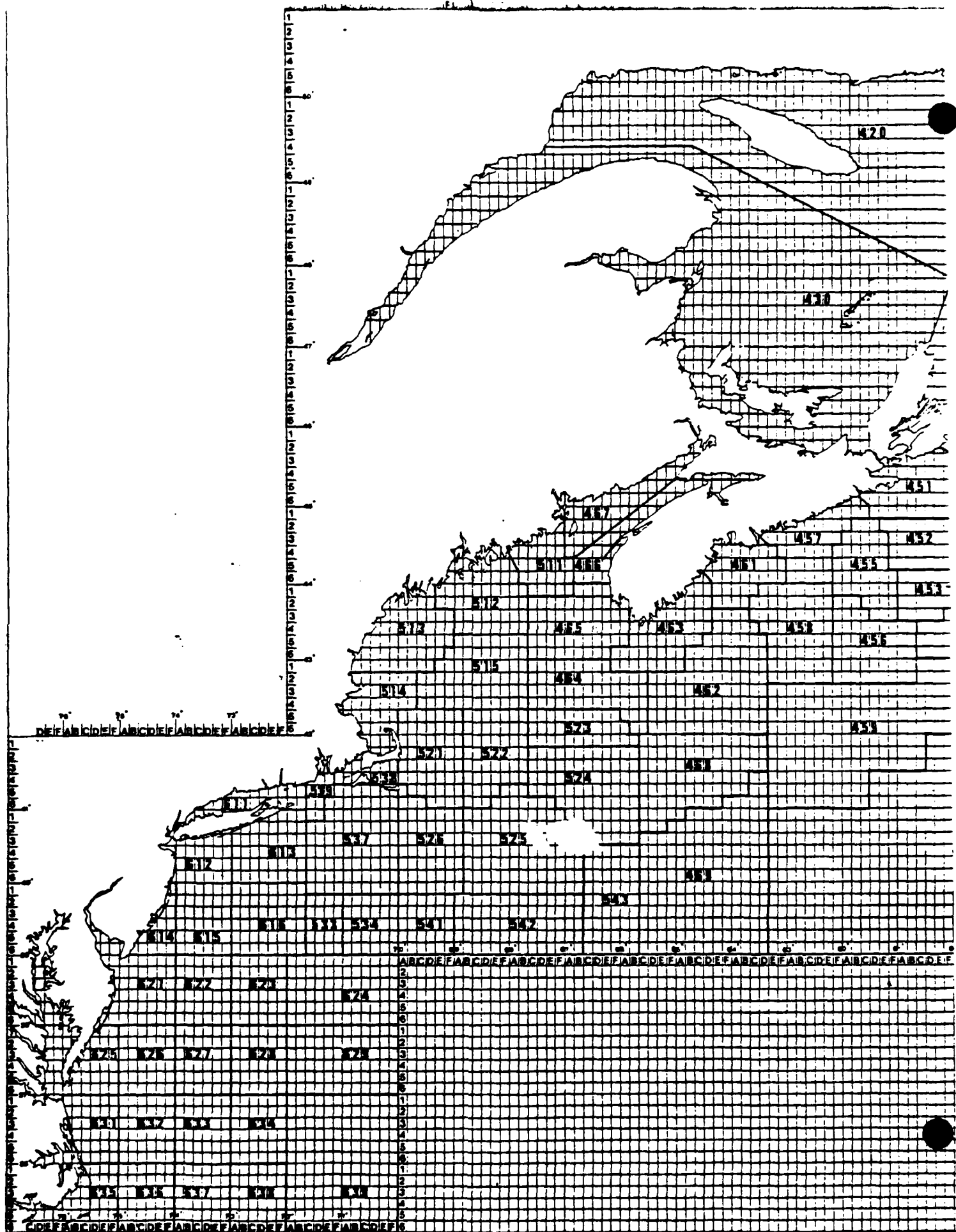
TABLE 3.D.1-1

1

LANDINGS IN AREA 514

| SPECIES            | TOTAL METRIC<br>TONS OFF N.E.<br>COAST OF U.S. | TOTAL POUNDS<br>FOR EACH SPECIES<br>IN AREA 514 | TOTAL METRIC<br>TONS FOR EACH<br>SPECIES IN 514 | SPECIES IN 514<br>AS PERCENTAGE OF<br>TOTAL OFF N.E. COAST |
|--------------------|--|---|---|--|
| BLUEFISH (023)     | 4,279  | 158,712   | 71.99   | 1.7%   |
| BUTTERFISH (051)   | 12,425   | 53,427  | 24.23   | 0.2%   |
| COD (081)          | 52,570   | 7,350,695                                       | 3,334.25  | 6.3%   |
| CUSK (096)         | 2,187  | 195,476   | 88.67   | 4.1%   |
| WINFLOUNDER (120)  | 14,685   | 2,558,483                                       | 1,160.52  | 7.9%   |
| SUNFLOUNDER (121)  | 14,197   | 19,710  | 8.94  | 0.1%   |
| WITFLOUNDER (122)  | 6,546  | 1,737,096                                       | 787.94  | 12.0%  |
| YELLOWTAIL (123)   | 17,819   | 1,319,006                                       | 598.30  | 3.4%   |
| AM PLAICE (124)    | 10,143   | 3,265,541                                       | 1,481.24  | 14.6%  |
| HADDOCK (147)      | 14,311   | 1,269,828                                       | 575.99  | 4.0%   |
| RED HAKE (152)     | 2,330  | 1,651,624                                       | 749.17  | 32.2%  |
| WHITE HAKE (153)   | 7,504  | 702,423   | 318.62  | 4.2%   |
| MALIBUT (159)      | 136  | 7,550   | 3.42  | 2.5%   |
| SEA HERRING (168)  | 33,447   | 19,902,069                                      | 9,027.52  | 27.0%  |
| HACKEREL (212)     | 14,007   | 1,112,472                                       | 504.61  | 3.6%   |
| HENHADEN (221)     | 251,788  | 52,152,510                                      | 23,656.22                                       | 9.4%   |
| REDFISH (240)      | 4,792  | 327,776   | 148.68  | 3.1%   |
| POLLOCK (269)      | 20,491   | 5,629,373                                       | 2,553.47  | 12.5%  |
| DOGFISH (352)      | 4,392  | 8,164,094                                       | 3,703.21  | 84.3%  |
| SKATES (365)       | 4,134  | 461,163   | 209.18  | 5.1%   |
| SILVER HAKE (509)  | 21,432   | 9,819,091                                       | 4,453.91  | 20.8%  |
| WOLFFISHES (512)   | 1,124  | 331,657   | 150.44  | 13.4%  |
| CRAB (700)         | 57,722   | 0   | 0.00  | 0.0%   |
| LOBSTER (727)      | 20,154   | 45,381  | 20.58   | 0.1%   |
| SHRIMP (736)       | 3,227  | 522,229   | 236.88  | 7.3%   |
| QUAHOG IN (748)    | 149,120  | 0   | 0.00  | 0.0%   |
| CLAM SOFT (769)    | 168,038  | 205,597   | 93.26   | 0.1%   |
| SEA SCALL (800)    | 24,028   | 689,969   | 312.97  | 1.3%   |
| SQUID LG (L) (801) | 11,720   | 34,415  | 15.61   | 0.1%   |
| SQUID S (I) (802)  | 1,776  | 8,860   | 4.02  | 0.2%   |
| TOTALS:            | 950,524  | 119,696,227                                     | 54,293.85                                       | 5.7%   |

\*POUNDS CONVERTED INTO TONS: 1 TON EQUAL TO 2204.6 POUNDS



NATIONAL MARINE FISHERIES (NMFS) STATISTICAL AREAS FIGURE C-1

### 3.D.2. SHIPPING

According to maps published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, the location of the Massachusetts Bay Disposal Site does not have any significant impacts in the main shipping lanes into Boston Harbor. MBDS is north of the harbor shipping lanes and therefore does not interfere with commercial channel traffic.

### 3.D.3. MINERAL, OIL, AND GAS EXPLORATION AND DEVELOPMENT

According to the U.S. Department of the Interior Minerals Management Service (MMS, 1983), there are no oil or gas exploration sites in the Massachusetts Bay Disposal Site.

### 3.D.4. GENERAL MARINE RECREATION

Other marine recreation, for example whale watching, has to be taken into consideration when discussing MBDS. There have been a number of sightings of whales in the vicinity of the disposal site. Various site seeing vessels pass through MBDS in order to reach areas where whales have been spotted. Data were not collected on recreational fishing and other sight seeing activities in the area of MBDS. The existence of MBDS only serves as a navigation aid (Buoy A) for whalewatching.

### 3.D.5 MARINE SANCTUARIES

The MBDS is not located within any designated marine sanctuary. Stellwagen Bank, 5.5 km east of FADS has been suggested as a candidate for a marine sanctuary, but at this time is not under nomination.

### 3.D.6 HISTORIC RESOURCES

It is very unlikely that significant historic properties are contained within the Massachusetts Bay Disposal Site. There is no possibility that prehistoric sites would be found, as this area was not above sea level during the last glaciation, when Pleistocene megafauna and early Amerinds began migrating into New England (including sections of the exposed continental shelf) (Moi and Roberts, 1979). The only historic shipwrecks reported within MBDS are a steel-hulled Coast Guard boat which was blown up with plastic explosives (42° 25' N, 70° 34.5' W), and a 55 foot fishing vessel (42° 25.7' N, 70° 33.5' W), both of which sank in 1981 (Jim Dailey, NOAA, pers. comm.). There exists only a very minor possibility that unrecorded historic wrecks are within MBDS. MBDS is outside of the main shipping channels, and is not associated with any particular hazard to navigation (e.g. rocks, shoals, etc), but it is conceivable that an unrecorded ship could have been damaged in a storm and drifted over the MBDS area before sinking (Bourque and Roberts, 1979). However, during the extensive bottom surveys conducted by the Corps of



Engineers, no evidence has been recovered that would indicate that an unrecorded wreck exists within the area. The only historic items noted during the surveys were twentieth-century barrels and drums of chemicals and/or low level radioactive wastes.

## CHAPTER 4 ENVIRONMENTAL CONSEQUENCES

### 4.A. Effects on the Physical Environment

As a result of previous work in the region and the recent studies conducted at the Massachusetts Bay Disposal Site, the environmental consequences of dredged material disposal and the interaction of the disposal operation with the physical environment can be well defined for this location. The following sections provide interpretation of the data presented under the Affected Environment Section as they relate to the observed and expected effects of disposal at MBDS.

#### 4.A.1 Short Term Effects

Short term effects are defined primarily as those which may occur during and immediately after disposal of dredged material and include such parameters as plume formation, convective descent, bottom collapse and initial dispersal of material.

Although disposal of dredged material and other waste has taken place in the vicinity of the Foul Area since the start of the century, control and monitoring of the disposal operations has only recently been accomplished during the past ten years. Consequently, the most pertinent data on the short term effects of disposal are available through studies conducted by the New England Division as part of the DAMOS program.

##### 4.A.1.a. Disposal Processes

Disposal of dredged material at MBDS is conducted through release from either disposal scows or hopper dredges. Regardless of the type of vessel utilized during a disposal operation, there are three major phases (Figure 4.A.1-1) which affect the behavior of dredged material:

- 1) The Convective Descent Phase, during which the majority of the dredged material is transported to the bottom under the influence of gravity as a concentrated cloud of material.
- 2) The Dynamic Collapse Phase following impact of the bottom where the vertical momentum present during the Convective Descent Phase is transferred to horizontal spreading of the material, and:
- 3) The Passive Dispersion Phase following loss of momentum from the disposal operation, when ambient currents and turbulence determine the transport and spread of material.

The major difference between hopper dredge and scow disposal results from the dredging operation, not the disposal process. The hopper dredge utilizes a hydraulic pump to transfer the dredged material from the bottom to the surface, a process that entrains a substantial amount of water and effectively breaks down the cohesiveness of the dredged material. As a

result of this process, the hopper-dredged sediment tends to be relatively homogenous and fluid. In cases where scow disposal occurs following clamshell dredging of cohesive sediments, the dredging procedure has less effect on the geotechnical properties of the sediment. Therefore, the material remains cohesive and is often transferred to the disposal site as large clumps of sediment.

In shallow water, the difference in the dredging procedure often results in a different type of deposit with the clamshell/scow material creating a more distinct mound formation with thin flank deposits, while the hopper dredge will produce a broader, more uniform deposit. In either case, the lateral extent of the deposit remains essentially the same. If the sediment to be dredged is a high water content, non-cohesive silt/clay deposit or unconsolidated sand, the difference between a hopper and scow disposal operation is relatively small. Each disposal load will create a broad thin deposit, which will gradually accumulate at the disposal site as more disposal operations occur.

During the Convective Descent Phase of the disposal process, water is entrained with the disposal cloud resulting in a gradual decrease in the density of the discharged material. If the water is deep enough, the density reduces to a value approaching the surrounding water and neutral buoyancy is attained. At that point, the vertical motion of the cloud ceases and passive dispersion of material occurs through transport by ambient currents. Studies by Stoddard et al. (1985) have shown that for a relatively large disposal vessel (4000 m<sup>3</sup>), the depth of neutral buoyancy is greater than 300 meters. Since the MBDS location has an average depth of less than 90 meters, it is safe to assume that neutral buoyancy will not occur at this location and that the dredged material will impact the bottom during the Convective Descent Phase.

The fact that the dredged material reaches the bottom during the Convective Descent Phase is extremely important in assessing the potential transport of material during the disposal process. Bokuniewicz et al. (1978) measured the rate of convective descent as approximately 1 m/sec during three separate disposal operations. Therefore, at the MBDS site, where the average depth is approximately 90 meters, the majority of material can be expected to impact the bottom within two minutes of disposal. Since the maximum current velocities measured during this program were approximately 30 cm/sec (Figure 3.A.2-16), the worst case transport of material during convective descent would only amount to 36 meters. This is well within the error of positioning of the disposal vessels and, therefore, the effect of currents, either tidal or non-tidal, on the shape or distribution of the disposed dredged material deposit would be negligible. This is in agreement with observations made at other disposal sites within the New England area (Morton, 1986) where, even in regions of strong, oscillatory tidal flow, no orientation of the dredged material deposit in the direction of tidal current has been observed.

Since the thermocline in the vicinity of MBDS occurs at depths less than 20 meters (Figure 3.A.2-4), it is safe to assume that at that depth, the dredged material will be in the Convective Descent Phase and the density of the disposal plume will not be close to neutral buoyancy. Therefore, the relatively small fluctuations in the ambient water density associated with the thermocline will have no effect on the majority of the dredged material which will be transported directly to the bottom.

The entrainment of water during the Convective Descent Phase and the residual dispersal of sediment washing out of the disposal vessel will result in some portion of the dredged material remaining in suspension throughout the water column after disposal. It can be expected that, in the case of cohesive sediments, slightly more of this material will be dispersed during a hopper dredge operation as opposed to scow disposal because the sediments would be in a more fluid state. However, in either case, the relative percentage of dispersed material is small compared to that transported to the bottom in the Convective Descent Phase. Several investigators, including Bokuniewicz (1980), Johnson (1978), and Tavoraro (1982) have all estimated the amount of material remaining in suspension, either through in-situ observation or modelling of the physical processes. These estimates range from 3 to 5% maximum (dry mass basis) depending on the conditions existing at the site and the properties of the dredged material.

Since these suspended sediments are not transported as part of the Convective Descent Plume, the ultimate fate of this material depends primarily on its settling rate and the ambient currents in the area. Fine silt particles, which are the predominant materials remaining in suspension, settle in quiescent waters at a rate of 0.7 cm/sec (Stoddard et al., 1985). Therefore, the time required to settle to the ambient bottom of 90 meters at MBDS would be nearly four hours. Assuming the "worst case" 50 cm/sec currents present in the area, this would result in transport of the particles for a distance of more than 4 km, well beyond the margins of the disposal site. This theoretical estimate is extremely conservative since 30 cm/sec currents generate sufficient turbulence to keep such fine sediments in suspension indefinitely; in fact nearly any current in excess of 5 cm/sec is sufficient to transport fine silt (Hjulstrom, 1935). Consequently, one should assume that essentially all fine silt particles left in suspension following disposal will be dispersed beyond the margins of the disposal site and that these sediments will be diluted until they are part of the background suspended sediment load of the region.

It is important to note that the contribution of this suspended dredged material to the overall suspended sediment concentration of the site is minuscule. Assuming a  $4000 \text{ m}^3$  disposal load, with a sediment density of  $1.2 \text{ gm/cm}^3$ ; if 10% of the sediment remains in suspension, and is dispersed over a  $1 \text{ km}^2$  area, 90 m deep, then the increase in suspended sediment concentration for that volume of water would be 0.005 mg/l. Since the average suspended sediment load in the area is 1 mg/l (Morton,

1984) the initial contribution of this sediment is less than 0.5%. Furthermore, this concentration will decrease at an exponential rate as the material is dispersed during transport away from the disposal site and will be virtually undetectable within a short period (hours) following disposal.

Several investigators have been able to track disposal plumes for short periods of time (Prøni, 1976; Bokuniewicz, 1978; Morton, 1984) and have documented the return to ambient conditions. There have been some instances, (Prøni, 1976; Morton, 1984) where increased concentrations of material have persisted at depths exhibiting strong density gradients (thermoclines) for extended periods of time, but never more than several hours.

The only quantitative measurements related to the disposal of dredged material in the vicinity of MBDS were made by Morton (1984). These measurements were conducted during a single dump from the hopper dredge SUGAR ISLAND on 1 February 1983. The dredge was operating in the President Roads channel dredging silt sediments and dumping the material at a designated Loran-C coordinate in the Massachusetts Bay Disposal Site. At that time, the major questions raised relative to the use of a hopper dredge for projects in New England centered around the behavior of silt material during disposal. Previous experience had shown that, in general, cohesive silts dredged by a clamshell/scow operation were immediately transported to the bottom during the Convective Descent Phase, and therefore, produced a relatively small plume. A concern existed that the hopper dredge technique would entrain water with the silt and break down any cohesiveness in the sediment so that disposal would generate a large, slowly settling plume that might transport significant quantities of material for substantial distances.

Consequently, the emphasis of this program was placed on examination of plume behavior through a combination of acoustic tracking and in-situ sampling. The R/V EDGERTON was configured for tracking the plume with a dual channel (50 and 200 KHz) Acoustic Remote Sensing System manufactured by Datasonics Inc. and the SAIC Precision Navigation System utilizing a Del Norte Trisponder positioning system ( $\pm 2$  meter accuracy).

The Datasonics Model DFS-2100 system provided simultaneous dual channel operation with high power output, low receiver noise levels and calibrated control of signal level which permits monitoring of extremely low concentrations of material in the water column, and acquisition of quantitative concentration levels when correlated with ground truth sampling. On this study, ground truth data were obtained from the M/V HUDSON RIVER, a support vessel supplied by Great Lakes Dredge & Dock Co. Samples of the water column were obtained during the plume tracking operation using Niskin bottles. The HUDSON RIVER was located in the plume by the EDGERTON and a messenger was dropped to trip the bottles.

Observations of the disposal plume created by the SUGAR ISLAND were conducted on 1 February at 1600 under relatively calm conditions. The EDGERTON positioned herself immediately astern of the dredge and moved over the disposal point as soon as dumping occurred. Figure 4.A.1-2 indicates the track of the EDGERTON during the next 1 1/2 hours as she tracked the plume. The striped section of the chart indicates the spatial distribution of the plume 15 minutes after disposal while the cross-hatched section shows the spatial distribution one hour later. During the 75 minute survey period, the maximum extent of dispersion was approximately 750 meters in a southeasterly direction. This represents a dispersal rate of 16 cm/sec or 0.3 knots.

Although this spatial distribution provides an indication of net transport, the acoustic records provided a much more detailed view of the plume dissipation. Immediately after disposal, the 50 KHz channel had substantially stronger reflections than the 200 KHz channel indicating that relatively coarse particles were in suspension. Furthermore, both channels indicated a narrow column of material extending from the surface to the bottom which rapidly expanded into a turbidity cloud in the lower portion of the water column. These phenomena strongly suggest that the material dumped by the hopper dredge acted in the same manner as material dumped from scows in that most of the sediment was transported to the bottom in a convective flow, which, upon impact with the bottom, spread radially and deposited most of the dredged material in a turbidity deposit within a few minutes of disposal. This was verified by sampling the resulting deposit which showed no increased expansion resulting from the hopper dredge operation (Morton, 1984).

In summary, whether the disposal operation is conducted with either a hopper dredge or scow, both theoretical and observational data indicate that the majority of the dredged material will be transported to the bottom at MBDS as a discrete plume during the Convective Descent Phase. If the material dredged is cohesive silt, the scow disposal is more apt to result in a concentration of cohesive clumps of material on the bottom and the hopper dredge is more apt to disperse slightly more material into the water column. However, in both cases, the differences will be small; the total area of the bottom covered by the dredged material will be similar and the amount of material lost as suspended sediment will be a low percentage of the total transported to the site.

#### 4.A.1.b Mound Formation/Substrate Consolidation

As discussed in the previous section, most of the sediments disposed at the MBDS site, whether from hopper dredge or scow, will be transported to the bottom during the Convective Descent Phase. When this material reaches the bottom, the vertical momentum will be transferred to horizontal momentum during the Dynamic Collapse Phase. Depending on the geotechnical properties of that sediment, one of two types of deposit will form. If the material consists primarily of cohesive silt, then a concentration of cohesive clumps, interspersed with soft mud will be

created. This deposit will be surrounded by a deposit of mud that extends beyond the clump area for some distance. If the material is sand, or non-cohesive silt, then the deposit can be expected to be more uniform.

In either case, the overall spread of the material will be similar, since the potential energy available for both types of disposal is essentially identical, and the transfer of vertical to horizontal momentum will take place in the same manner when the material impacts the bottom. The main difference in the deposit results from the distribution of kinetic energy between the large cohesive clumps which will absorb a great deal of energy without much horizontal movement and the more fluid muds which will readily flow until that energy is dissipated.

The overall size and thickness of the resulting disposal mound will depend on the amount of material disposed at the site and the navigation control exercised during the disposal effort. In order to insure that disposal of dredged material occurs in a controlled manner, it is reasonable to expect that a taut-wire moored buoy will be deployed at this site. Using such a buoy, restriction of the disposal operation to a 50 meter radius is possible and the input of dredged material can be considered as a point source. In this manner, overall management of the distribution of dredged material is possible through controlled placement of the buoy.

Based on the results of previous operations at this site, it is apparent that navigation control of the disposal operation is critical for proper management. Disposal operations conducted from scows under tow by tugs during 1982 and 1983 were not closely controlled and the resulting deposit was spread over a large area (see Section 3.A.2) (Morton, 1984 and 1985). More recent projects during 1983 and 1985 made use of taut-wire moored buoys and Loran-C navigation to increase the precision of disposal positioning. As a result, the deposits formed on the bottom covered substantially smaller areas (see Section 3.A.2).

Recent work completed during January 1987 (see Section 3.A.2) has demonstrated that the disposal of dredged material at MBDS resulted in a broad, low deposit spread evenly over an area similar to that covered by disposal in more shallow waters. The spread of material was likely due to a combination of inadequate control over the location of the scows during disposal (up to 300 meters from the buoy), the depth of the water (90 m), and the behavior of the dredged material during descent. Figure 3.A.2-3 presents a schematic diagram of disposal in shallow water, as compared with the deeper water at MBDS.

The major difference in the disposal of dredged material in shallow and deep water results from the loss of kinetic energy through entrainment of water during the Convective Descent Phase so that, in deeper water when bottom impact occurs, the lateral motion during Dynamic Collapse is substantially less than in shallow water. The result is a more uniform, broad deposit over essentially the same area of bottom.

The effect of precise navigation controls on mitigating measures such as capping or dilution of the deposit can have important implications for disposal management. Improved control of scows could reduce the area covered by dredged material and, therefore, reduce the amount of capping material required. For example, if dredged material covered an area of bottom with a 500 m radius, similar to the deposit created during the 1986 disposal operations, a minimum of 441,000 m<sup>3</sup> of material would be required to produce a cap deposit 0.5 meter thick extending 30 m beyond the edge of dredged material. However, due to the fact that the cap is formed by attempting to deposit individual scow loads at evenly spaced points over the dredged material deposit, it would most likely require somewhat more material than this to insure that the cap was at least 0.5 m thick over the entire area. If the area were reduced to a 300 m radius, through very tight disposal operations that would be required in an actual capping operation, the minimum amount of capping material becomes 171,000 m<sup>3</sup>. Table 4.A.1-1 presents the minimum volume of material required to cap contaminated material covering a range of areas.

An alternate approach might be controlled disposal of both "contaminated" and "clean" material at the same location resulting in mixing and dilution of the contaminants. Such a deposit could be easily monitored for containment, recolonization and bioaccumulation of contaminants by infauna. Should significant adverse impacts be observed, then substantial amounts of clean material could be deposited to effectively cap the site.

Although capping has not been conducted at MBDS, previous operations have demonstrated the effectiveness of disposal control in restricting the spread of material. This is the single most important factor in a capping operation. If, as will be shown in later sections, the disposal location is a containment site then, given sufficient material, capping should be feasible.

#### 4.A.2 Long Term Effects

Long term effects are changes in the environmental conditions that occur and persist over extended periods of time as a result of dredged material disposal and include such factors as: permanent changes in the topography of the site, alterations in the benthic habitat as a result of disposal, and changes in current patterns or hydrographic structure that may result from the topographic features created.



#### 4.A.2.a Bathymetry

Previous disposal operations at MBDS have not created any significant topographic features, although the accumulation of material in specific areas has altered the bottom conditions. Studies of the disposal process (Morton, 1984; SAIC, 1987) have indicated that control of the disposal point can restrict the spread of material to relatively small areas; consequently, the potential exists for future operations to accumulate more sediment into more typical mound features.

The capacity of the MBDS area for disposal of dredged material is virtually unlimited relative to the amount of sediment that would have to be deposited at the site before significant topographic changes would occur that might impact the circulation pattern of the area or the stability of deposits. If disposal operations resulted in covering a circular area of 1 km<sup>2</sup> radius, then a mound two meters high would require more than 6 million m<sup>3</sup> of material to be deposited. Such a mound would have virtually no effect on currents and the depth change would be so small that the forces acting on the sediment would be unchanged. It is significant to note that 6 million m<sup>3</sup> is more dredged material than has been deposited at the site during the past twelve years.

#### 4.A.2.b Circulation and Currents

The circulation in the vicinity of MBDS has been well characterized by Butman (1977) whose conclusions were fully supported by the results of measurements taken during this site evaluation program. In general, the surface currents at MBDS are dominated by tidal oscillations resulting in maximum currents of 30 cm/sec oriented in a NE-SW tidal ellipse (see Section 3.A.2). Deeper in the water column, the velocity of the tidal current decreases significantly until the average maximum current near the bottom (85 m) is only 4-5 cm/sec (see Section 3.A.2). Both the surface and bottom currents may be significantly altered by the presence of strong easterly storm events. During Hurricane Gloria, wind stress-induced near-surface (10 m) currents reached values of 70 cm/sec (Appendix Table I-1). Near-bottom currents were affected by the basin-wide response to build-up of sea level on the western margin of Massachusetts Bay which resulted in southeasterly currents on the order of 20 cm/sec (see Section 3.A.2) (Figure 3.A.2-20).

The major characteristic of the bottom currents is their relatively low velocity, which under virtually all conditions measured to date are insufficient to erode deposited dredged material and, under most conditions, are not sufficient to transport material coarser than fine silt. The 20 cm/sec currents resulting from easterly storm events would be sufficient for transport if another mechanism (such as wave action or bioturbation) were available to resuspend the sediment. If transport were to occur the net direction would be toward the Stellwagen Basin south of the disposal site, where the sediments would be expected to accumulate in areas of existing fine silt deposits (see Section 3.A.2).

#### 4.A.2.c Potential for Resuspension and Transport

There are three major factors affecting the resuspension and transport of dredged material at the MBDS site:

- 1) the physical properties of the sediments,
- 2) the current regime described above, and
- 3) the wave field.

Bioturbation, can also have an effect, either through modification of the physical properties of the sediment or through physical injection of particles into the water column. However, it is the interaction of the three major factors which is of most concern when assessing the physical properties of a site for dredged material disposal.

The classic work defining the effect of physical properties of sediment on potential resuspension and transport was that of Hjulstrom (1935) who developed a graphic representation of the relationship between the behavior of sediments as a function of grain size and water velocity (Figure 4.A.2-1). Although later work has refined and quantified these relationships, the basic theory and conclusions have remained valid. In general, whether the water motion is imparted by currents or wave energy, the higher the velocity (i.e. kinetic energy) of the motion, the greater the stress that is exerted on the sediment-water interface to cause resuspension of particles. From Figure 4.A.2-1, it is apparent that fine, unconsolidated sands in the range of 0.1 - 0.5 mm diameter are the most susceptible to erosion and, therefore, can be resuspended by the lowest water velocity. As would be expected, increased velocity (i.e. energy) is necessary to induce erosion of larger particles because of their greater mass. However, resuspension of finer sediments also requires higher velocity, to overcome the cohesive attraction of the particles. Furthermore, these finer sediments form a smooth, uniform interface which presents less surface area upon which frictional forces can act to transfer momentum from the water to the particles.

The three most significant concepts that can readily be derived from Figure 4.A.2-1 and applied to the evaluation of dredged material disposal are:

- 1) A minimum of 15 cm/sec is required to erode even the least stable material (fine sand)
- 2) It is more difficult to erode cohesive fine clay deposits (>50 cm/sec) than even the coarsest sand (30 cm/sec), and
- 3) Once erosion has taken place, even 15 cm/sec is sufficient to keep any particles of sand size or smaller in suspension.

When applying the principles developed by Hjulstrom (1935) to the problem of sediment stability at a disposal site, it is important to take into account the inherent variability of a dredged material deposit. A typical dredging project in New England can extend from the mouth of the estuary, where relatively coarse sands may be present, through deep channels which accumulate large volumes of fine silt, to small pockets of fine silt-clay material dredged from between docks. All of these sediment types are dumped together at the disposal site so that the resulting deposit usually consists of a central mound composed of a mixture of coarse and fine materials surrounded by an apron of highly fluid mud.

As discussed in previous sections, the type of dredging and disposal operation can also have an effect on the physical properties of the deposit (see Section 3.A.2). If dredging has been conducted through clamshell operations, much of the fine sediment will be transported to the site as cohesive clumps of material which are very resistant to erosion. However, these clumps extend up into the bottom boundary layer of the ambient current field and generate turbulence. This turbulence imparts greater stress on the sediment than would be typical of the same current over a smooth surface and, therefore, the clumps are subjected to comparatively greater erosion forces. Conversely, the hopper dredging operation tends to break the cohesive bonds of the material and forms deposits more susceptible to resuspension. However, the fluid nature of the material results in a sediment surface that is relatively smooth and more difficult to erode.

At the disposal site, all of these factors interact in both space and time and, therefore, prediction of the actual stability of a dredged material deposit is extremely difficult. However, some basic understanding of the effect of sediment properties on stability is available. Bottom currents in excess of 15 cm/sec have the potential to erode the highly fluid mud due to the turbulent flow created by the cohesive clumps and, like the plume material remaining in suspension, it could be transported beyond the margins of the disposal site. Bottom currents typical of MBDS would not favor this process, rather the fluid mud would begin to consolidate. As this material is consolidated or removed, the surface of the deposit consists of materials more resistant to erosion. In effect, this process "armors" the surface of the mound making erosion of the deposit more difficult. As will be discussed in the next section, this "armoring" of the sediment surface can either be reinforced or weakened over time by bioturbation factors.

In order to evaluate the potential of a disposal site for containment of dredged material, it is necessary to assign some measure of erosion resistance to such deposits. Although, at this time, there are no data available regarding the properties of the specific sediments to be dredged and disposed at the site, an estimate can be made based on the previous discussion through specification of an equivalent grain size and corresponding current velocity from Figure 4.A.2-1. Assuming that "armoring" of the sediment surface has occurred, the resistance to erosion

will certainly have increased to the level of medium sand or fine silt, requiring a current velocity greater than 35 cm/sec to cause significant resuspension. In reality, velocities on the order of 45 cm/sec might be more appropriate once the deposit has reached equilibrium. Using 35 cm/sec as an arbitrary, but conservative, estimate for resuspension potential, it is then possible to evaluate the currents at a specific disposal site or to compare between two sites. In practice, dredging and disposal permitting procedures require that definitive sediment property data be defined for each project; therefore, during management of the site, some refinement of this arbitrary number is possible on a project by project basis.

During the entire period of the site evaluation measurements, the near-bottom current speeds never exceeded 25 cm/sec (Figure 3.A.2-17 and 18) and the highest reported maximum velocity (Butman, 1977) is only 30 cm/sec. Since 35 cm/sec is a conservative estimate of the velocity needed to induce sediment resuspension, it is clear that the MBDS site can be considered as a containment site with respect to currents.

Because MBDS is located on an exposed coastline, the currents alone are not sufficient to classify the area as a containment site; the effects of wave action must also be considered. If the water motion created by wave action is sufficient to cause resuspension, then even the low currents described above may be capable of transporting material for large distances, thus making the area a dispersal site. For virtually any exposed site on the coastal shelf, there are certain to be some periods, during major storms, when the wave energy will be sufficient to resuspend sediments. However, the frequency of occurrence of such conditions must be evaluated to determine whether or not the risk associated with disposal is warranted. If the frequency of resuspension is sufficiently low, then the location can still be classified as a containment site.

The impact of wave action on sediment resuspension is clearly defined in the Shore Protection Manual (CERC, 1984) as shown in Figure 4.A.2-2. In this figure, a dimensionless bottom velocity is predicted as a function

$$\frac{U_{\max}(-d)T}{H} \quad \text{Eq. II.2-1}$$

of water depth (d) and wave period (T). For a given water depth, the bottom velocity is greater with longer wave period. Conversely, for a given wave period, the bottom velocity is greater at shallower water depths. A third factor which must be considered is the wave height (H) in Equation II.2-1. For a given depth and wave period condition, greater wave heights result in the greater bottom velocities ( $U_{\max}$ ).

Combining all of these parameters, the characteristics of waves which could cause resuspension at the MBDS site can be determined as shown in Table 4.A.2-1. This table assumes the same sediment parameters as described above (see Section 4.A.2) resulting in a bottom velocity of 35

cm/sec required to initiate resuspension of typical dredged material. Substituting this value of 35 that, at the ambient depth of 85 meters, waves with periods on the order of 12 to 13 sec are required to initiate motion, since waves with shorter periods must have excessive wave heights (i.e. 23 m (75 ft) for a 10 sec wave) which could never occur at MBDS. However, the longer period waves must also be quite large, 4.7 m (15 ft) and 3.5 m (11 ft) at 15 and 16 second periods, respectively to initiate resuspension, and as will be shown later, they occur infrequently.

Once the critical wave parameters for sediment erosion are established, the frequency of occurrence of such conditions must be determined. Using wave hindcasting procedures presented in the Shore Protection Manual (CERC, 1984), it is possible to predict the parameters of waves as a function of wind speed, fetch and duration. Since the MBDS disposal site is located so close to the Massachusetts coastline, fetch from the westerly direction is severely limited and the longest period waves that could ever be developed from that direction would be 6 sec. Therefore, no waves from the west would ever be expected to cause resuspension at MBDS. Conversely, waves from the easterly direction have essentially an unlimited fetch and, given sufficient wind speed and time to develop, could be expected to impact the sediment stability. However, because storms generating easterly winds approach the MBDS region over land from the south and west (see Section 3.A.1), the time during which the ocean is exposed to high wind speeds is relatively short. Therefore, Table 4.A.2-2 presents the predicted wave characteristics generated by storms with wind speeds from 31 to 67 mph blowing over ocean waters for periods of 3, 6 and 12 hours. By comparing the results of the calculations presented in this table with the data in Table 4.A.2-1, it is possible to that would cause resuspension of dredged material. In Table 4.A.2-2, those conditions are to the right and below the dashed line. Therefore, a storm a typical northeaster (see Section 3.A.2.a) would have to blow at 50 mph for at least 12 hours in order to resuspend disposed dredged material at MBDS. Smaller storms, with winds on the order of 30-40 mph would never be expected to cause significant erosion.

The frequency of such storms is difficult to determine since they occur sporadically. Data from the National Climatic Data Center (1986) suggests that storms in excess of 45 mph for more than 12 hours occur on the average of once every three to five years (see Section 3.A.2-2). Bohlen (1981) (Table 3.A.2-3) documented that 22 northeast storms with winds in excess of 45 mph occurred in Massachusetts Bay during the period of 1920-1980, supporting the estimate provided by NCDC. Fourteen of the 22 storms documented by Bohlen had winds in excess of 50 mph for more than 12 hours, making the average occurrence of a storm event once every four years.

Neumann et al. (1978) indicate that the frequency of hurricanes for any ten mile section of coastline in the southern Maine area is on the order of once every 150 years. During the period of this study, the only close approach of a hurricane was Hurricane Gloria which occurred on 27

September 1985. The storm intersected the coastline in the middle of Long Island and had significantly moderated by the time it reached the vicinity of MBDS. During the storm, the maximum gust recorded was 70 mph and the highest sustained velocity was 55 mph. However, the duration of the storm was very short with increased wind velocities lasting for less than four hours (NCDC, 1986).

Based on the fact that winds in excess of 50 mph for 12 hours or more are required to generate waves which could cause resuspension at the MBDS site, and the fact that such storms occur on an irregular, infrequent basis, it seems prudent to consider that the MBDS site be classified as a containment site. On the rare occasions that resuspension of sediments occurs, the duration of the event is certain to be short (<1-2 days) and the effect of the storm on more shallow deposits of natural sediments is certain to increase the suspended sediment load of the entire region. Therefore, the addition of small amounts of sediment dispersed from the MBDS disposal site would be insignificant and undetectable.

#### 4.A.2.d Bioturbation

Bioturbation can either enhance or reduce the potential for sediment resuspension, depending on the type of benthic infauna present and their interaction with the sediment (Rhoads and Boyer, 1982). In most cases where burrowing organisms are active, pelletization and "dilation" (increasing porosity) of the fine-grained sediment eliminates the cohesiveness between particles, making the seafloor more susceptible to erosion. Furthermore, bioturbation by larger animals breaks down the cohesive clumps into smaller features, making them more accessible to the burrowing infauna. Conversely, some tube-dwelling animals, such as amphipods and small polychaetes, create mats of tubes cemented together by organic secretions which serve to stabilize the sediment surface, making it very resistant to erosion. Similarly, the resulting mucous from enhanced microbial production also tends to stabilize the sediment surface.

In most cases, deposition of dredged material will drastically alter the structure of the benthic community in the immediate vicinity of the deposit; the magnitude and duration of this impact on the benthic population will depend on the amount and type of material deposited, the level of contaminants present in the disposed material, and the time of year when disposal occurs. The sequence of infaunal communities which recolonize an area after a disturbance (such as deposition of dredged material) is described in detail in Rhoads and Boyer (1982). Biological assemblages which stabilize the sediment are more frequently present during the first stages of recolonization, while the deeper-burrowing animals which decrease sediment shear strength gradually infiltrate the site over a period of time.

Most estimates of the stress required for initiation of sediment motion, including those discussed in the previous sections, depend on empirical laboratory criteria, such as the work of Hjulstrom (1935).

These estimates are based upon experiments using flat beds of abiotic, uniform non-cohesive sediments. Currently, one of the most intensely-studied topics in the field of marine research is the effect of animal-sediment-fluid interactions on sediment stability. In particular, the potential for sediment resuspension under given hydrodynamic conditions as a function of the type of biological assemblage present is being examined (e.g., Rhoads et al., 1978; Yingst and Rhoads, 1978; Eckman et al., 1981; 1981; Grant et al., 1982; Carey, 1983; Jumars and Nowell, 1984; Eckman and Nowell, 1984; Muschenheim et al., 1986). Unfortunately, there are still no absolute predictions which can be made concerning sediment transport, even if the biological community is known. Without doing controlled experiments, biological processes cannot be absolutely classified as stabilizing or destabilizing. The different functional types of assemblages described above make different contributions to stabilizing or destabilizing the sediment-water interface and these contributions are not linearly additive. Most research to date documents the effects of a single biological process on initial sediment motion; however, even though these estimates are important, it is the sum of all biological and physical effects within a given sediment which determines stabilization or destabilization.

Figure 4.A.2-3 is a REMOTS image from MBDS in which the effects of bioturbation on sediment texture are readily apparent. Sediments such as these are more susceptible to erosion and transport than freshly deposited, cohesive dredged material that is either azoic or inhabited only by small tubicolous, opportunistic polychaetes characteristic of initial colonizing benthos. The intensive particle bioturbation characteristic of these mature, equilibrium communities is associated with fine-grained sediments with water contents greater than 60% and commonly over 70%.

Over time, the dredged material at MBDS will be progressively populated by Stage III infauna; this will be accompanied by further biogenic remolding, dilation, and pelletization of the sediment surface to depths comparable to those measured on the ambient seafloor. Typically, such biogenic processing is markedly seasonal, especially in coastal waters which experience large seasonal changes in bottom water temperatures. For each 10°C change in temperature, bioturbation rates can be expected to change by a factor of 2-3 due to the effect of temperature on metabolic rates. During the thermal maximum, the critical threshold erosion velocity may be significantly reduced as a result of this biogenic activity. However, it is important to note that bottom temperatures at MBDS do not vary significantly over the year (see Section 3.A.2.a) and that periods of highest temperature are least likely to have strong storm events which would create easterly winds. Therefore, the effects of bioturbation should be smaller and less variable over the seasons than in more shallow sites.

#### 4.A.3 Summary of Physical Effects

The Massachusetts Bay Disposal Site (MBDS) is located in the northern portion of Massachusetts Bay west of Stellwagen Bank. The topography of the site is sharply divided into two areas, a shoal region in the northeast quadrant of the area and a deep, relatively flat depression with an average depth of approximately 85 - 90 m over the remainder of the site. The shoal areas are covered with coarse sand deposits while the natural sediments in the deeper regions consist of fine silt deposits.

The MBDS region has been used for disposal of dredged material and other waste products for more than 50 years. Consequently, the center and western areas of the site are covered with dredged material deposits, however, there are no significant topographic features associated with those deposits. The dredged material deposits are relatively thin, broad layers consisting primarily of silts and some coarser sediments. There are localized regions with concentrations of cohesive clump deposits in the vicinity of disposal buoy locations.

The dredged material appears to be very stable once it has been deposited. Samples of material that had been in place for more than two years still displayed the reduced, high organic, black mud characteristic of dredged material from estuaries in the region. Side scan sonar and REMOTS surveys also documented the distribution of dredged material and presence of cohesive clumps in areas where disposal had taken place several years earlier. Consequently, it is apparent that neither physical disturbance from currents and waves, nor bioturbation significantly affect these deposits.

The water column at MBDS is characteristic of the shelf regime throughout New England, with strong stratification near the surface during the late summer and isothermal conditions during the winter. Near-surface currents in the area are dominated by tidal flow in northeast-southwest directions with maximum tidal velocities on the order of 30 cm/sec. Based on the results of the current meter deployment in September 1987, the mid-water depths experience mean current velocities from 10 to 15 cm/sec with a dominant northwesterly flow. At the deeper depths, there was a secondary component to the southeast. Small amounts of fine-grained sediment separate from the dredged material plume during convective descent and remain in suspension. During periods when a well-developed pycnocline exists, these sediments could be concentrated at that level and potentially be transported away from the disposal point. The actual maximum amount of this material will be determined by the physical characteristics of the sediment, the volume of material disposed, and method of disposal but may range from 3 to 5%. When the pycnocline is near the surface, net transport would be in a SW or NE direction (Figure 3.A.2-24b).

Near-bottom currents are very low, averaging less than 7 cm/sec. Occasional higher velocities reaching up to 20 cm/sec in a westerly direction have been observed in near-bottom waters in response to easterly



storm events that occur during the fall or winter. No strong bottom currents were observed as a result of storm events, however moderate storm induced currents were in a westerly direction, not the southeasterly direction predicted by Butman (1977). Based on these data it is apparent that the near-bottom currents at MBDS are not sufficient to resuspend sediments. However, should resuspension occur for another reason, the currents generated in response to easterly storm events could be sufficient to transport material beyond the margins of the site. The wave regime in the vicinity of MBDS is controlled by the lack of fetch from a westerly direction and the fact that storms are duration-limited in their ability to generate waves. Since they generally approach the MBDS region over land from the south and west, northeast storms do not affect the waters of Massachusetts Bay until they are essentially at the site. Consequently the duration of these storms in Massachusetts Bay is quite short (maximum of 1-2 days). These limitations, combined with the depth of the site (>85 m), greatly restrict the generation of waves capable of causing resuspension of dredged material at MBDS. In order to generate waves of sufficient height and period to cause resuspension, an easterly storm must have winds in excess of 50 mph for a period of more than 12 hours. Such storms are rare, occurring approximately once every four years in the Massachusetts Bay region.

The combination of wind and wave conditions existing at MBDS and the evidence that previously deposited dredged material has remained unchanged over a several year period all support the conclusion that MBDS is a containment site. Dredged material deposited at MBDS can be expected to remain in place for extended periods of time although the surface of the deposit may be resuspended on rare occasions of severe easterly storm events. During these events transport of the resuspended material would be to the west and southwest.

Management of dredged material at MBDS should emphasize navigation control of the disposal operation. Recent surveys at MBDS have shown that dredged material was restricted to an area with a radius of approximately 500 m for a deposit of about 250,000 m<sup>3</sup> placed in the vicinity of a taut-moored buoy. Tighter control of the scows with respect to dumping at the buoy could potentially reduce this area. If this accuracy could be maintained throughout the entire disposal operation, capping of contaminated sediments may be a feasible mitigating measure at MBDS. Accurate navigation control would also permit dilution of contamination levels through deposition of both contaminated and relatively uncontaminated sediments at the same location. Such an approach, where a quantity of uncontaminated sediments would be deposited simultaneously or soon after disposal of contaminated material could effectively reduce any risk associated with the disposal of small amounts of contaminated sediments.

In summary, the designation of MBDS as a disposal site for dredged material would appear to be an appropriate use of this portion of Massachusetts Bay. It is apparent that material deposited at the site will remain in place, and since the area has previously been used for disposal of dredged material and other waste products, such a designation would not expand the area of the sea floor affected by future disposal operations.

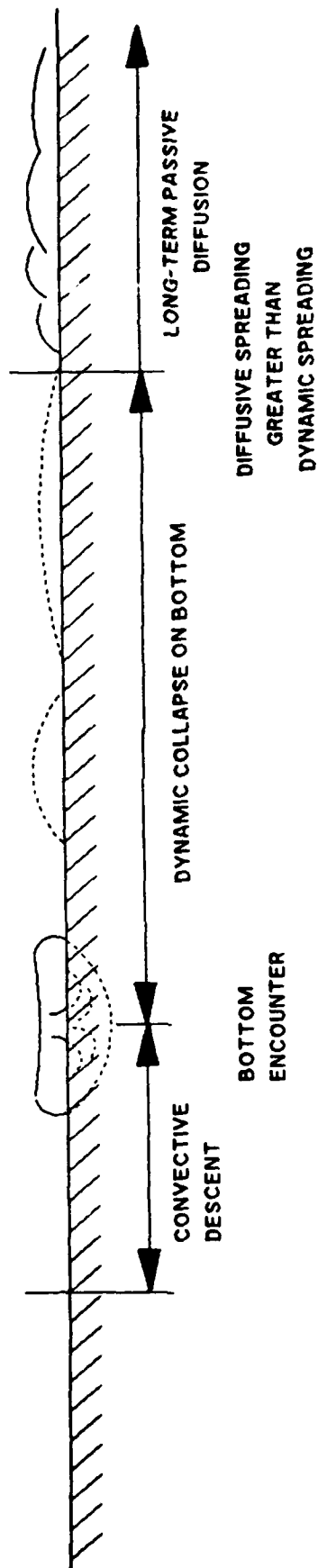
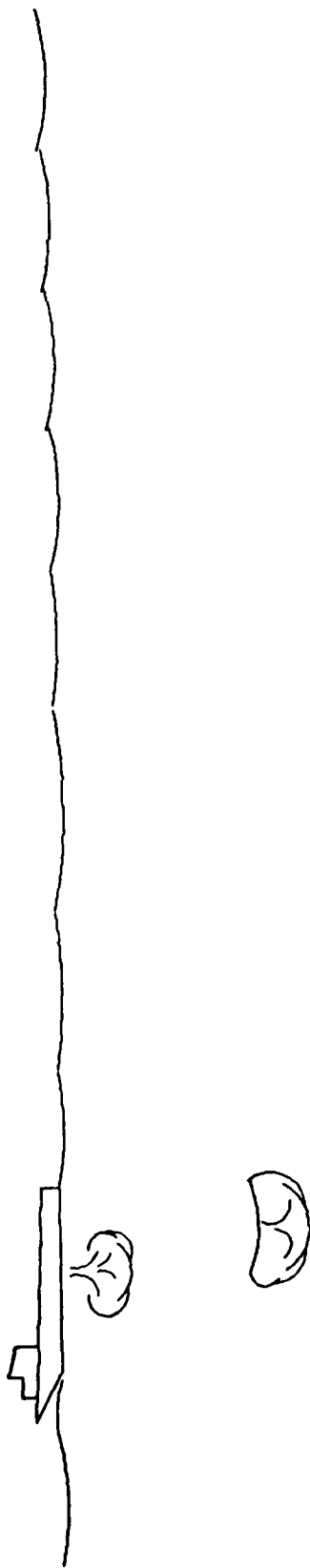
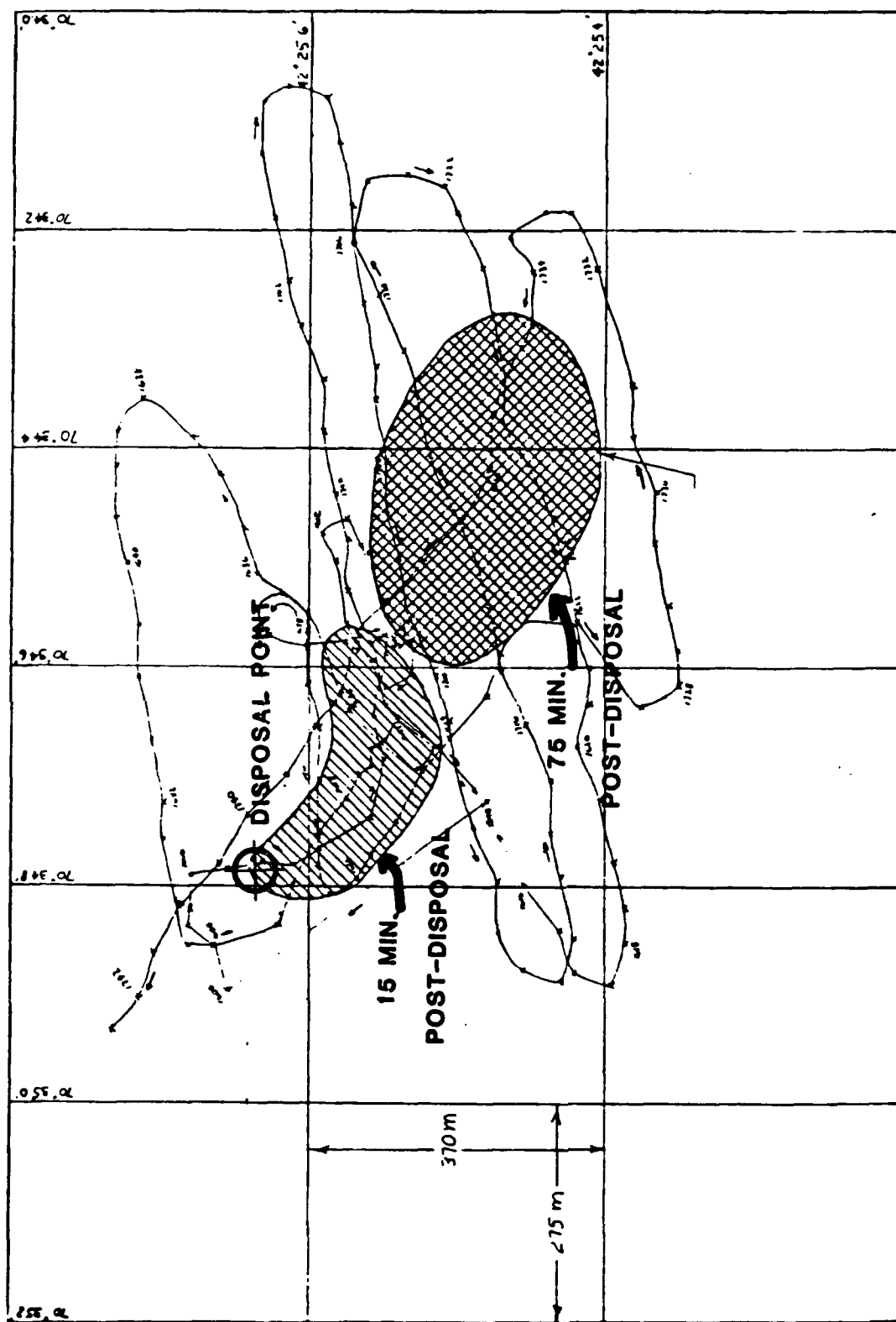
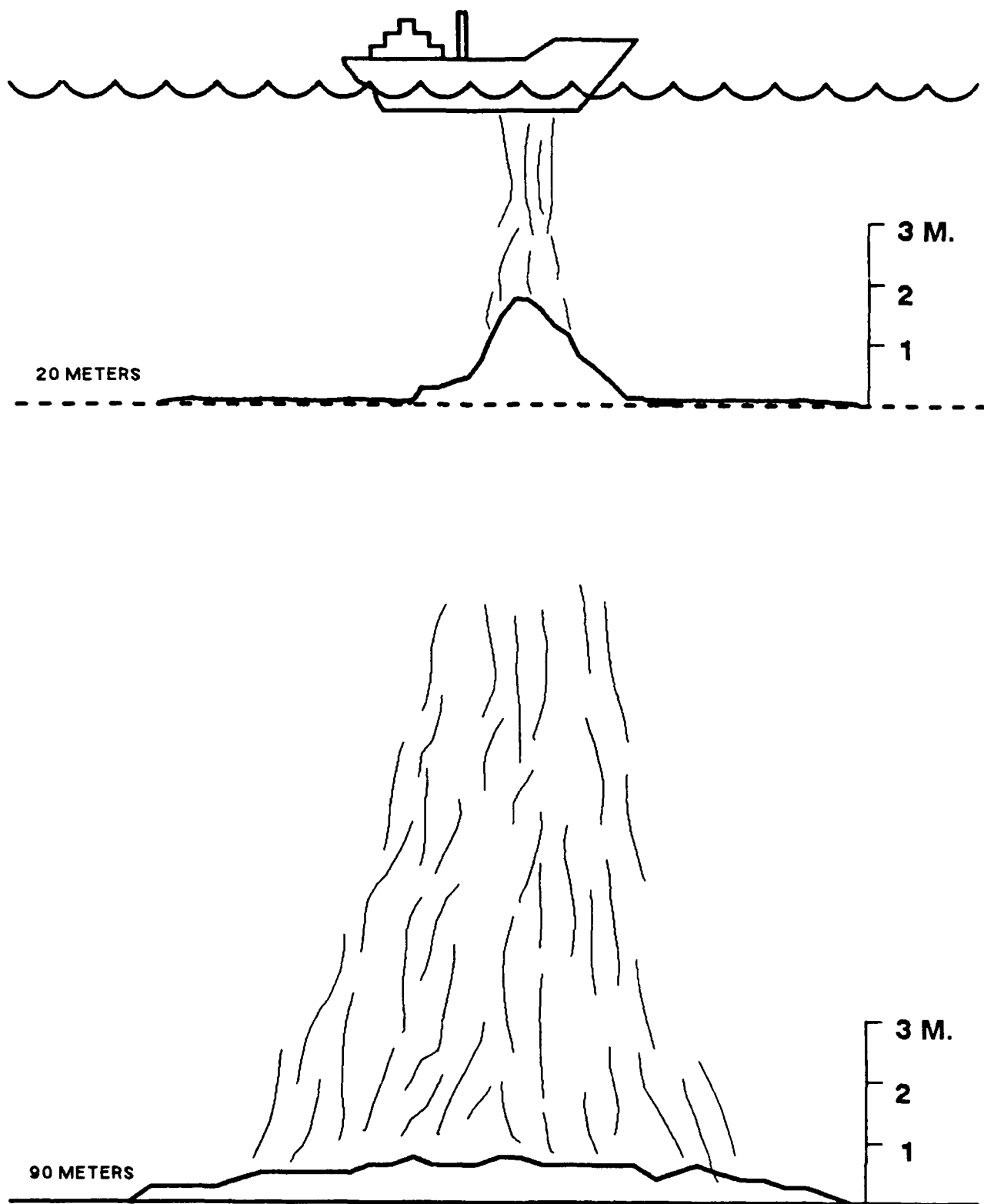


Figure 4.A.1-1 Schematic diagram of phases encountered during dredged material disposal operations (from Brandsma & Divoky, 1976)

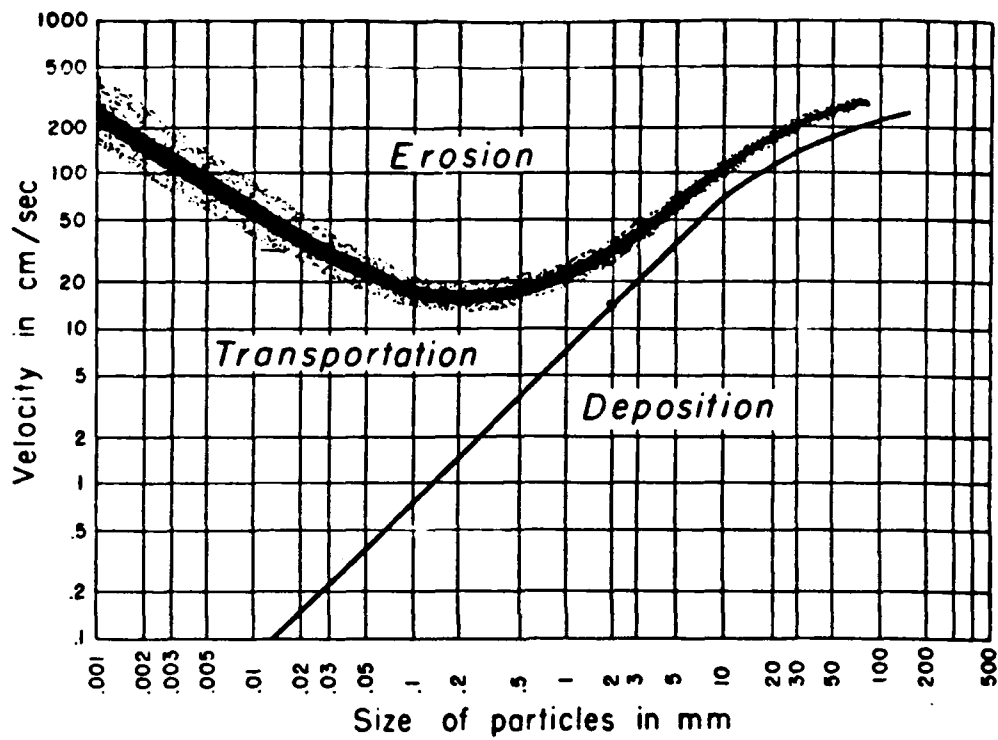


**Figure 4.A.1-2 Ship's track and disposal plume dispersion following disposal operations by the Hopper Dredge SUGAR ISLAND (1 Feb., 1983) (from Morton, 1984)**

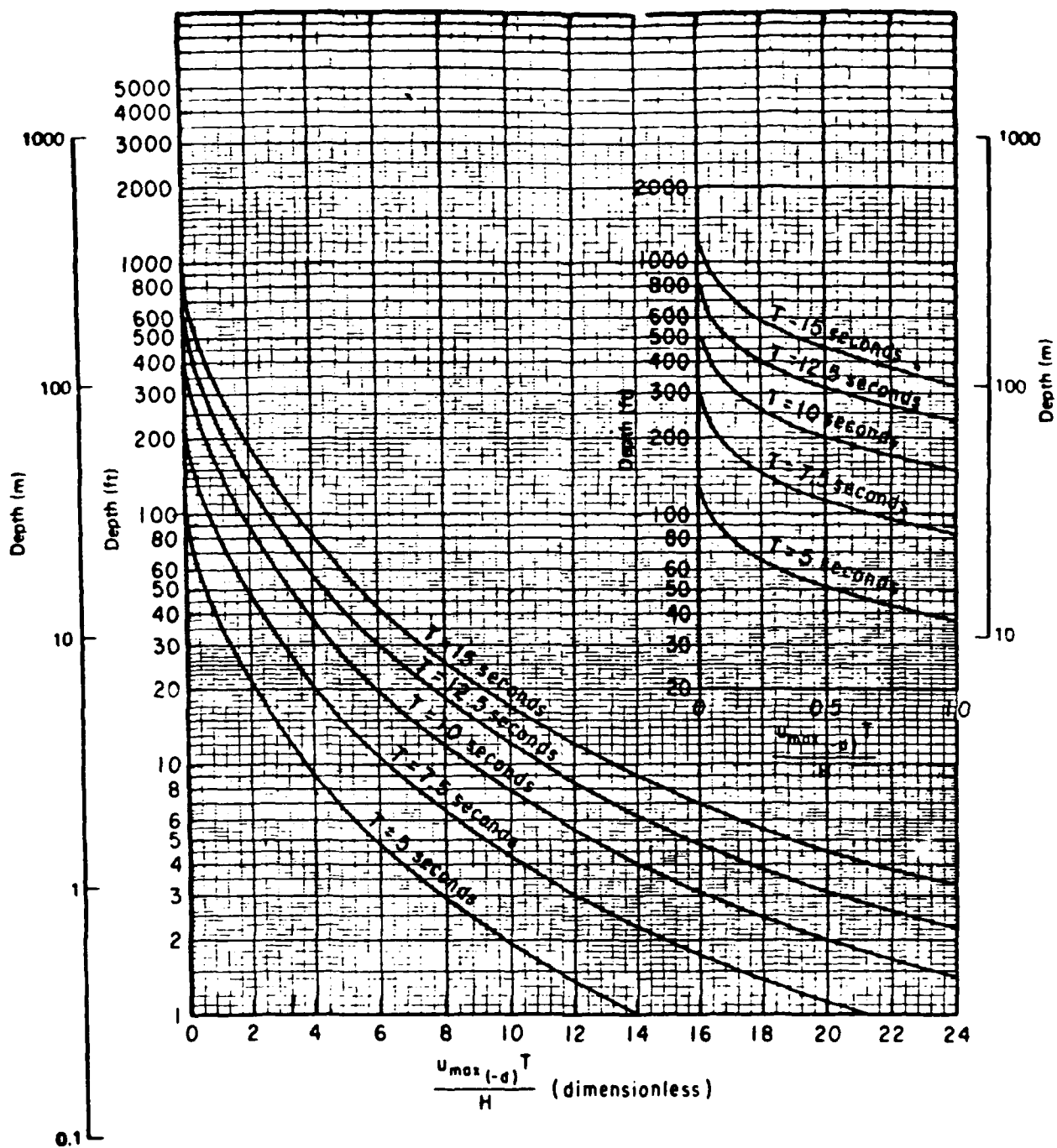
# DREDGED MATERIAL DISPOSAL



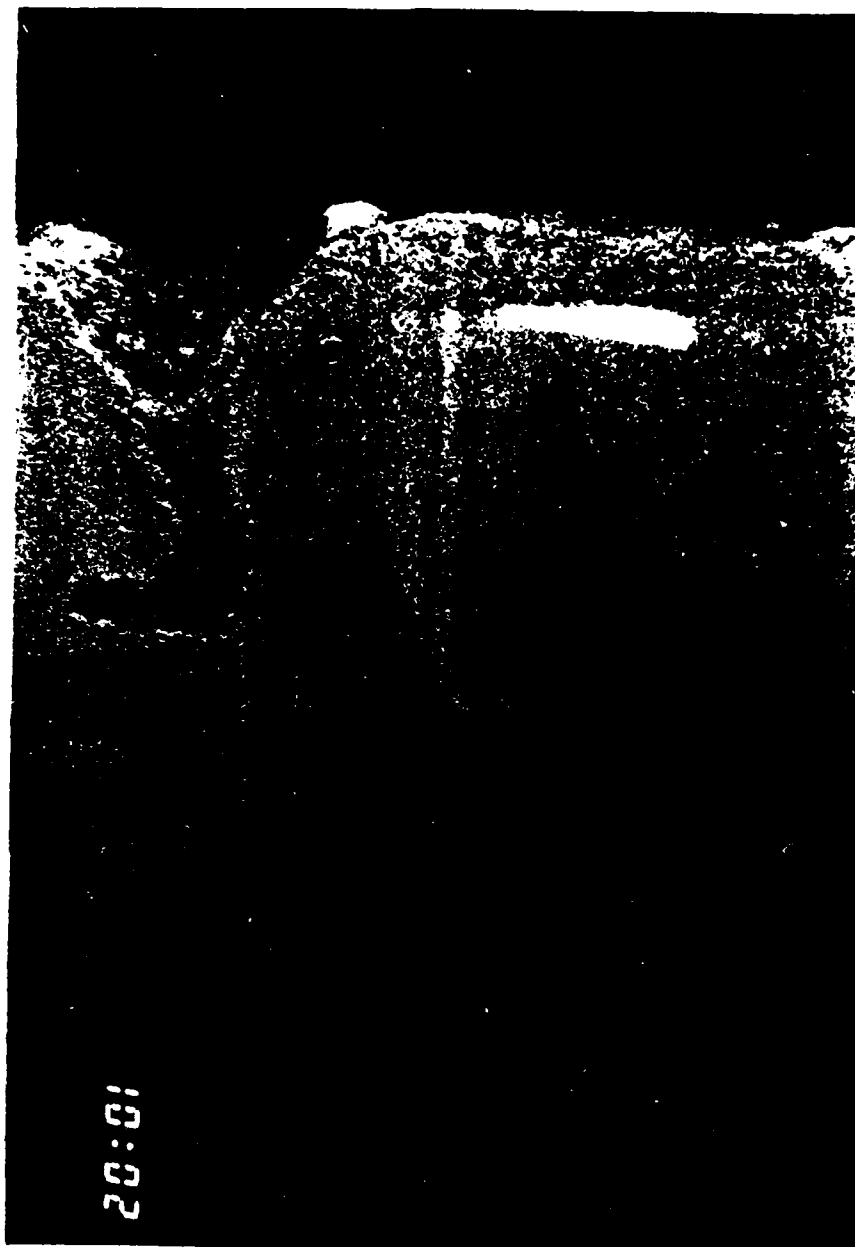
**Figure 4.A.1-3** Schematic comparison of the difference in the dredged material deposit resulting from disposal in relatively shallow (20 m) and relatively deep (90 m) water



**Figure 4.A.2-1** Potential for sediment erosion, transport and deposition as a function of grain size and bottom current velocity (from Hjulstrom, 1935)



**Figure 4.A.2-2** Dimensionless maximum bottom velocity as a function of water depth and wave period (from CERC, 1984)



**Figure 4.A.2-3** REMOTS image from MBDS indicating the effects of bioturbation on sediment texture



Table 4.A.1-1

Volume Estimates\* of Capping Material Required for a Range  
of Areas Covered with Dredged Material

(Volumes are X 1000m<sup>3</sup>)

| Cap<br>Thickness<br>(meters) | Radius of Dredged Material (meters) |     |      |      |      |      |      |      |      |  |
|------------------------------|-------------------------------------|-----|------|------|------|------|------|------|------|--|
|                              | 200                                 | 300 | 400  | 500  | 600  | 700  | 800  | 900  | 1000 |  |
| 0.5                          | 83                                  | 171 | 290  | 441  | 623  | 837  | 1082 | 1356 | 1666 |  |
| 1.0                          | 166                                 | 342 | 581  | 882  | 1247 | 1674 | 2164 | 2717 | 3333 |  |
| 1.5                          | 249                                 | 513 | 871  | 1324 | 1870 | 2511 | 3246 | 4076 | 4999 |  |
| 2.0                          | 332                                 | 684 | 1162 | 1765 | 2494 | 3348 | 4328 | 5434 | 6666 |  |

\* Assumes that the cap material extends approximately 30 meters beyond the dredged material.

Table 4.A.2-1

Minimum wave parameters required to cause resuspension of typical dredged material deposited at the Massachusetts Bay Disposal Site

| Wave Period<br>(sec) | $\frac{U_{\max}(-d)^T}{H}$ | H<br>(m) |
|----------------------|----------------------------|----------|
| 10                   | .15                        | 23       |
| 11                   | .35                        | 11       |
| 12                   | .45                        | 9        |
| 13                   | .75                        | 6        |
| 14                   | .90                        | 5.4      |
| 15                   | 1.10                       | 4.7      |
| 16                   | 1.60                       | 3.5      |

Table 4.A.2-2

Predicted Deepwater Wave Characteristics  
Duration Limited Conditions  
(USACE, 1984)

| Wind Speed<br>mph | Beaufort<br>Sea State | Significant Height in Feet<br>(Period in Seconds) |            |             |
|-------------------|-----------------------|---|------------|-------------|
|                   |                       | 3 hrs   | 6 hrs      | 12 hrs      |
| 31                | 7<br>Moderate<br>Gale | 1.5 (4.8)   | 2.5 (6.6)  | 4.4 (9.8)   |
| 34                |                       | 1.6 (5)   | 2.9 (7.2)  | 4.8 (10.5)  |
| 37                |                       | 2.0 (5.5)   | 3.2 (7.5)  | 5.5 (11)    |
| 40                | 8<br>Fresh<br>Gale    | 2.1 (5.6)   | 3.6 (8.0)  | 6.0 (11.5)  |
| 43                |                       | 2.4 (6.0)   | 4.0 (8.5)  | 6.9 (12)    |
| 46                |                       | 2.7 (7.1)   | 4.6 (8.7)  | 7.6 (12.5)  |
| 49                | 9<br>Strong<br>Gale   | 2.9 (6.5)   | 4.8 (9.0)  | 8.2 (12.7)  |
| 52                |                       | 3.2 (6.7)   | 5.2 (9.5)  | 9.1 (13.0)  |
| 55                |                       | 3.3 (6.8)   | 5.8 (9.6)  | 9.8 (13.5)  |
| 58                | 10<br>Whole<br>Gale   | 3.6 (7.0)   | 6.1 (10.0) | 10.7 (14.0) |
| 61                |                       | 4.0 (7.25)  | 6.7 (10.0) | 11.3 (14.5) |
| 64                |                       | 4.3 (7.5)   | 7.0 (10.5) | 11.9 (14.8) |
| 67                | 11<br>Storm           | 4.6 (7.5)   | 7.6 (11.0) | 12.8 (15.0) |

\*Conditions below and to the right of this line are sufficient to cause dredged material resuspension at  
MBDS

#### 4.B. Effects on the Chemical Environment

##### 1. Water Quality

The water quality at MBDS is subject to spatial and temporal fluctuations as well as physical stratification. Physical trends in the water column are reported in Section 3.A.1. Chemical parameters measured during the course of this study are defined in Section 3.B.1.

The process of disposal has the potential to elute some portion of the various chemical contaminants adsorbed to the dredged sediment particles. Chemical concentrations of contaminants are typically adsorbed to particulates in the parts per million (ppm or mg/kg) range, while water quality concentrations are typically in the parts per billion (ppb or ug/l) range. The solubility of sediment adsorbed contaminants varies with the properties of the particles and water column. The interaction of the two produce elution of contaminants. Gilbert (1975) obtained water quality samples in the water column at MBDS during a disposal episode at 0, 30, 60 and 72 meters. The 30 meter and bottom concentrations contained elevated turbidity (as measured by the suspended solids concentration), as well as copper, zinc, PCB and especially lead. The available zone of initial dilution within MBDS boundary is  $8.62 \times 10^{11}$  liters. Five percent of this volume ( $4.31 \times 10^{10}$  liters), for example, is sufficient to dilute water with virtually any elutriated concentration of contaminants. Most contaminants occur in the water column from elution of dredged material through the ppb (ug/kg) range. If PCB concentrations, for example, were highly elevated in dredged material, exhibiting an elutriate test value as high as 5.0 ppb, assuming a complete elution of all PCB (not typically more than 1-10%) and a 4000 m<sup>3</sup> barge disposal, applying the dilution calculation of EPA/COE (1977), the required zone of initial dilution is equal to 0.04% of the available water column within MBDS.

Disposal of dredged material elutes contaminants only for the short duration of the disposal event. The percentage of MBDS water column required to dilute contaminants to ambient concentrations can be calculated using EPA/COE (1977) handbook Appendix H. Even potentially high elution values would be rendered unmeasurable within 5% of MBDS dilution volume. Therefore concentrations of contaminants are unlikely to be present in a majority of MBDS water column in excess of the EPA Water Quality Criteria, after initial dilution.

#### 4.B.2. Sediment Chemical Environment

The disposal of dredged material at MBDS is anticipated to continue at the present rate or potentially increase with the advent of major construction activities proposed for the greater Boston Region. The chemical quality of major improvement type dredging is different than for maintenance type dredging. The disposal of uncontaminated "Boston Blue Clay" from areas underlying Boston Harbor, should not add to the chemical contaminant levels at MBDS and in fact may serve to lower average sediment contaminant concentrations. The short-term and long-term effects of disposal activities, in regards to chemical quality, are perhaps best predicted by analyzing the quality of previous disposals.

Table 1-2 summarizes the quality of material disposed and also gives the quantities of dredged material disposed of at MBDS since 1976. An average chemical quality and standard deviations of test results are presented along with the maximum concentration identified in the data. The weighted average data are most representative of total impacts, since it compensates for large volume disposals versus small volume disposals, the former's chemical impact being more significant than for the latter. These data are highly biased toward the worst case, or elevated contaminant levels because testing protocol calls for samples of sediment chemistry to be taken from areas in the system that are anticipated to be contaminated. Less contaminated dredged material is therefore not equally represented.

##### a. Short-term Impacts

Short-term disposal impacts on the quality of chemicals partitioned in the sediment and biota can be given a year to year time scale. Although highly variable, annual quantities averaged 178,310 cubic meters per year (233,209 cubic yards per year) for the current disposal site between 1976 and 1987. The approximately 180,000 cubic meters were predominantly silt/clay (60%) with sand/gravel comprising 40% of the material (Table 1-2).

Stellwagen Basin is a natural settling area for fine particulates in the Massachusetts Bay/lower Gulf of Maine system. Sediment accumulation rates for the area are approximately 1 mm per year, with estimates of sediments at 30 cm deep being 300-500 years old (Gilbert, 1976). Short-term impacts are influenced by the quality of materials settling on MBDS and the disposed material. The approximately 11 million square meter surface area of MBDS therefore receives approximately 110,000 cubic meters of fine-grained particulates from natural processes. The chemical quality of this sediment should be representative of the total inputs and dilutions of contaminants to the Massachusetts Bay system if evenly distributed.

#### 4.B.2.a. Short Term Impacts

The short-term chemical alterations at the disposal site can be predominantly associated with the fine-grained dredged material with an average chemical signature as listed in Table 1-2. This is combined or layered with the cleaner material to form physically and chemically heterogeneous deposits of material throughout the site.

Using the MDWPC (1978) classification of dredged material, the ambient sediment regime at MBDS is altered with inputs of moderate levels (Class II) of mercury, lead, chromium, arsenic and high levels of oil and grease. Comparing the MBDS-ON to MBDS-REF data (see Section 3.B.3), ANOVA testing revealed statistically significant elevations of lead, zinc, chromium and copper on dredged material in comparison to reference areas outside MBDS and unimpacted areas within MBDS ( $p < 0.05$ ).

Arsenic inputs are classified as moderate (Class II) by the MDWPC (1978) system, but their quantities (avg. 12.63 ppm input, 6-13 ppm ambient) are in the range of ambient or unimpacted substrates (Barr, 1987). The anomaly is not, therefore, that there is not statistical difference between arsenic at reference versus impacted area, but the classification range of 10 to 20 ppm as elevated encompasses natural levels in this system.

Mercury levels at MBDS-ON were below ( $< 0.01$  detection levels) 0.14 ppm, much lower than the 0.68 ppm weighted average for inputs. Mercury was historically used as a biocide in antifouling marine paints. The elevated inputs (Class II 0.5 to 1.0 ppm) are in the lower end of the MDWPC moderate range and may be biased by larger inputs in the 1970's. In any event, mercury contamination was not observed at the MBDS stations sampled.

Copper was statistically (Anova,  $p < 0.05$ ) elevated at MBDS in comparison to MBDS-REF. Quantitatively, however, MBDS-ON average copper levels were low at 69.8 ppm and in reasonable agreement with the weighted average 104.6 ppm inputs.

Zinc inputs to MBDS had a weighted average of 170.8 ppm, while MBDS-ON concentrations were similar averaging 220 ppm. The input range is in the upper Class I category ( $< 200$  ppm) while the in-situ average (220 ppm) was in the lower Class II (200-400) range.

Nickel and cadmium had low levels of input from past disposal operations and were not present in significantly elevated quantities at MBDS nor were they statistically different from reference areas.

The concentration of lead at the disposal site is higher than ambient and statistically elevated in comparison to the reference station. Lead inputs from past disposal operations averaged 126.8 ppm, in a Class II range. Concentrations of lead at MBDS-ON agreed with inputs averaging 156.8 ppm (also Class II).

Chromium levels at the disposal site were statistically elevated in comparison to reference values. Weighted average chromium inputs to the disposal site were 105.9 ppm, a low Class II (100-200 ppm) value. This was in good agreement with in-situ concentrations of chromium averaging 115 ppm at MBDS-ON.

The elevated weighted average of oil and grease levels input to MBDS averaged 2.13%, a Class III (>1.0 %) value according to MDWPC. The disposal area was not sampled for oil and grease contents, but field notes identified MBDS-ON dredged material as having "an oily sheen". Specific oil and grease compounds of concern are Polycyclic Aromatic Hydrocarbons which were found as 0.51 ppm of flouranthene. Phthalate compounds were also found at MBDS at a 7.6 ppm level. PAH levels have not been well documented for low versus high classifications in dredged material. The levels reported here are not exceptional in the perspective of urban dredged material.

Impacts resulting from deposition of dredged material will have a short-term impact of imparting a water column chemical signature (see 4.B.1) that potentially could be accumulated by filter feeding benthos as tissue residue in biota. The deposit feeding benthos that pioneer the disposal mound have the potential to uptake any contaminants present in the substrate. The results of tissue residue analysis for this project indicates limited bioaccumulation potential at MBDS.

The elevated input levels of oil and grease coincide with the 2.2 - 2.5 ppm dry weight PAH residue, in organisms from the disposal mound. The 0.7-0.8 ppm dry weight PCB levels are indicative of bioaccumulation of PCBs by Nephtys incisa. These two organic compounds are known to accumulate in biotic tissues (Kay, 1984). PCB concentrations in sediments alone are not the controlling factor for PCB accumulation potential (Rubinstein et al., 1983). Partitioning and assimilation/elimination rates of PCB renders the compound more or less susceptible to biotic uptake (Brownawell and Farrington, 1985; O'Connor, 1984). PAH compounds vary in their availability to organisms. Many organisms have the ability to metabolize PAH compounds (Clarke and Gibson, 1987; Giesy et al., 1983).

Therefore, PAH and PCB accumulation in organisms at MBDS are not directly correlated to bulk sediment concentrations. The evaluation of dredged material for bioaccumulation potential according to Sec. 103 of MPRSA would be necessary to predict PCB or PAH uptake, since bulk sediment chemical tests alone do not suffice. This testing has previously predicted PCB uptake from contaminated material in the same low magnitude as found in-situ at MBDS (NED, unpublished data). Therefore the organic residue levels found in organisms from the disposal mound are in good agreement with the predisposal testing predictions.

Bioaccumulation of metals does occur with food uptake and physical adsorption for copper, zinc, selenium, arsenic, chromium, lead, and cadmium (Kay, 1984, Langston & Zhon, 1986). Different organisms also show

varying regulation abilities that eliminate tissue residues of metals (Amiard, 1987). Lake et al. (1985) demonstrated uptake of PCB, PAH, copper, and chromium by polychaetes exposed to dredged material with elevated levels of these contaminants.

The metal levels at the disposal site are not sufficiently elevated to impart significant physical adsorption or food uptake in the organisms analyzed. Subtle contaminant uptakes occurring throughout Stellwagen Basin would be difficult to identify in respect to isolating system wide (i.e. Massachusetts Bay) impacts from disposal events.

#### 4.B.2.b. Long Term Impacts

The prediction of long term impacts on the Massachusetts Bay environment resulting from continued disposal of dredged material at MBDS can be broken into a systems perspective and a biological community perspective. The Stellwagen Basin area, as well as other deep basin areas in Massachusetts Bay receive fine particulates settling at rates of approximately 1 mm annually (Gilbert, 1976). The resultant 110,000 cubic meters deposited on MBDS annually by natural sedimentation rates will have a chemical signature paralleling the background contaminant loads in the Massachusetts Bay System.

The approximately 180,000 cubic meters of annually disposed materials dredged from urban harbors imparts a chemical signature at MBDS reflecting the contaminant levels of those harbors. The most probable sources of contaminants in urban harbor sediments and in the fine particulates settling at MBDS are local wastewater treatment plant effluents, various point source and non-point source runoffs.

The impacts of disposal physically disturb benthic communities at the disposal point through burial and turbidity impacts. The chemical impacts of disposal are more subtle. Separating the impacts of sublethal chemical effects on benthic community structure from natural variability in biological population is inherently difficult. The biological monitoring program at MBDS is designed to examine gross impacts at the benthic community level, while monitoring the contaminant uptake and incorporation into the benthos at the organismal level. The long-term impacts of dredged material disposal at the community levels should be viewed in a system's perspective.

The Massachusetts Bay system receives approximately 500 million gallons per day of primary effluent from Boston's wastewater treatment plant alone. NPDES permits, non-point source runoff and the many other wastewater treatment plants all make additional contributions to the chemical loading into the system. Metals data on the Boston wastewater treatment plant's predicted secondary effluent, once all plant improvements are constructed and operational (year 2020), is presented in Table 4.b.2-3. This plant has traditionally been operating at a primary level of treatment which allows much greater levels of chemicals to enter the



system. Future plans for conversion to secondary effluents are being implemented. The most recent estimates for suspended solids loading into the Massachusetts Bay System from the primary effluent is approximately 100,000 kg/day (MWRA, 1987). These solids enter the system at a point 35 kilometers west of MBDS. (Future improvements call for primary, then secondary effluents to flow from a diffuser 18.5 kilometers west of MBDS.)

A comparison of the annualized mass loading of contaminants from the predicted secondary treatment effluent (year 2020) Boston Harbor treatment plant reveals dredged material disposal input of contaminants to the Massachusetts Bay system is comparable or less than this one source. In context, the present primary effluent of only this single plant would then potentially represent considerably more contaminant inputs to the system than disposal of dredged material.

As stated in Section 3.a.2, 95 to 99% of all disposal material reaches the bottom at MBDS. In contrast, wastewater treatment effluent is extruded with its solids in suspension. The results of calculating a maximum (5%) potential material in suspension and dividing by the dilution zone available at MBDS ( $8.6 \times 10^{11}$  liters) are in Table 4.B.2-4. It is evident that even if all the annualized dredged material were disposed at MBDS at one event, and 5% completely dissolved into the water column, the EPA Water Quality Criteria would not be violated. This assumes a worst case scenario with dredged material data biased toward a more contaminated sediment profile than is likely to occur. Only 25% of the available mixing zone would be needed to bring all constituents within EPA criteria.

#### 4.B.3. Summary of Chemical Effects.

Reviewing the historical disposal data, the water column chemistry, the in-situ versus ambient sediment chemistry and the biotic tissue residue levels, it is evident that disposal of dredged material at MBDS imparts a chemical signature in a low to moderate (Cr, Cu, Pb and Zn) range for sediments and low range for tissue residues only of stations directly affected by disposal. These values are in agreement with the levels of contaminants detected in the dredged material prior to testing. Water quality impacts are temporary and limited to the immediate disposal event. The biological availability of contaminants seems to be restricted to persistent organics, particularly PAHs. Even these are in quantitatively low residue levels at MBDS and only at stations directly affected by disposal.

Table 4.B.2-1. Statistical Summary and Weighted Average  
of all Dredged Material Disposed at MBDS  
between 1976 and 1987.

|                                  | Concentrations are in ppm |       |        |        |        |        |        |       |      |       |      |
|----------------------------------|---------------------------|-------|--------|--------|--------|--------|--------|-------|------|-------|------|
|                                  | Hg                        | Cd    | Pb     | Cr     | Cu     | Ni     | Zn     | As    | PCB  | %VOL  | %OIL |
| Avg-ppm                          | 0.58                      | 2.02  | 96.50  | 88.17  | 65.31  | 24.08  | 134.70 | 8.44  | 0.25 | 2.08  | 1.09 |
| STD                              | 0.90                      | 2.19  | 106.62 | 116.32 | 84.12  | 24.28  | 145.91 | 11.34 | 0.62 | 2.44  | 1.77 |
| MAX                              | 6.46                      | 8.90  | 491.50 | 629.50 | 448.50 | 88.83  | 532.00 | 52.10 | 3.00 | 8.23  | 7.48 |
| Weighted Average                 | 0.68                      | 2.96  | 126.84 | 105.88 | 104.60 | 36.76  | 170.83 | 12.63 | 0.22 | 2.99  | 2.13 |
| Mass. Class II is greater than:  | 0.50                      | 5.00  | 100.00 | 100.00 | 200.00 | 50.00  | 200.00 | 10.00 | 0.50 | 5.00  | 0.50 |
| Mass. Class III is greater than: | 1.50                      | 10.00 | 200.00 | 300.00 | 400.00 | 100.00 | 400.00 | 20.00 | 1.00 | 10.00 | 1.00 |

Table 4.b.2-2. Disposal Volumes (cubic yards and meters)  
for MBDS inplace conversion - 0.65)

| YEARLY TOTALS | C.Y.    | C.M.    |
|---------------|---------|---------|
| 1987          | 118800  | 90400   |
| 1986          | 232122  | 177480  |
| 1985          | 273355  | 209066  |
| 1984          | 226369  | 173143  |
| 1983          | 282919  | 101582  |
| 1982          | 845819  | 530637  |
| 1981          | 315204  | 241019  |
| 1980          | 15108   | 11552   |
| 1979          | 91908   | 70277   |
| 1978          | 33116   | 25322   |
| 1977          | 50223   | 38403   |
| 1976          | 313558  | 205674  |
| GRAND TOTALS  | 2798502 | 1874554 |

Table 4.B.2-3.  
Predicted Concentration of Metals  
in Secondary Effluent  
Year 2020 (MWRA, 1987)

| <u>Chemical</u> | <u>Loading (Kg/Year)</u> |
|-----------------|--------------------------|
| Arsenic         | 685                      |
| Cadmium         | 756                      |
| Chromium        | 3,822                    |
| Copper          | 12,980                   |
| Lead            | 5,390                    |
| Mercury         | 216                      |
| Nickel          | 9,699                    |
| Selenium        | 4,796                    |
| Silver          | 325                      |
| Zinc            | 37,481                   |

Table 4.B.2-4. Average Annual Chemical Mass  
Disposed at MBDS.

|          | Total Mass<br>kg/year | Maximum (5%)<br>Potential in Suspension | Max. conc./dilution<br>zone ug/l | EPA Water Quality<br>Criteria (ppb) ug/l |
|----------|-----------------------|---|----------------------------------|--|
| Arsenic  | 2,698                 | 135                                     | 0.16                             | 69                                       |
| Cadmium  | 634                   | 32                                      | 0.04                             | 43                                       |
| Chromium | 22,619                | 1,131                                   | 1.31                             | 1,100                                    |
| Copper   | 22,345                | 1,117                                   | 1.30                             | 2.9                                      |
| Lead     | 27,096                | 1,355                                   | 1.57                             | 140                                      |
| Mercury  | 145                   | 5                                       | 0.01                             | 2.1                                      |
| Nickel   | 7,853                 | 393                                     | 0.46                             | 8.3                                      |
| Zinc     | 36,494                | 1,825                                   | 2.12                             | 58                                       |
| PCB      | 47                    | 2                                       | 0.0015                           | 0.03                                     |

Note: Based on approximately 178,000 m<sup>3</sup> of material as annualized MBDS disposal,  
using 1,200 kg/m<sup>3</sup> as a bulk density for dredged material to convert volume to mass.  
MBDS dilution zone = 8.62 x 10<sup>11</sup> liters

#### 4.C. Effects on Biota

##### 4.C.1. Effects on Plankton

Dredged material disposal activities at MBDS are unlikely to significantly impact phytoplankton populations in Massachusetts Bay. Any impacts to phytoplankton at MBDS will be related to short term changes in water quality in the immediate vicinity of a dredged material disposal plume. During a disposal event phytoplankton below the disposal barge will be exposed to shear stress, and to abrasion by high concentrations of suspended sediments. Small, flagellated species are likely to be more susceptible to damage by turbulent shear (Symada 1983) and abrasion than diatoms, many of which are armored with siliceous cell walls. Some phytoplankton may be carried below the euphotic zone with the descending mass or entrained water and dredged material. Additional plankton may become adhered to sediment, and subsequently sink below the euphotic zone (see Pequegnat, 1978).

Increased concentrations of suspended sediments in the vicinity of the disposal point will temporarily reduce the penetration of light through the water column, and may reduce phytoplankton productivity (Pequegnat, 1978). Although even low concentrations of suspended sediments (ca 10 mg/l) can reduce phytoplankton productivity in clear coastal waters (Smith, 1982), the area likely to be impacted by disposal activities is small. Using a simple, conservative model (see Table 4.C.2-1), it is estimated that, for a typical disposal event, the area of the water column at MBDS impacted by significant ( $> 10$  mg/l) concentrations of suspended solids is 22.5 hectares. This area is only a small fraction (2.1%) of the total surface area of MBDS, and an insignificant fraction (0.02%) of the total surface area of Massachusetts Bay. In addition, within hours of the disposal event, suspended solids concentrations will return to ambient levels (see section 4A).

Ocean disposal of dredged material may result in the release of nutrients and/or chemical contaminants into the water column (see Section 4.B.). The release of nutrients (particularly ammonia) may stimulate growth of phytoplankton entrained in the convective jet (Pequegnat, 1978). Because rapid dilution of a dredged material plume will occur at MBDS, however, there is no possibility that disposal could precipitate a sustained algal bloom.

Dilution of the disposal plume and settling of suspended solids, should quickly reduce contaminant concentrations in the water column to below levels likely to have an adverse impact on phytoplankton populations in the vicinity of MBDS. Within the disposal plume, however, elevated concentrations of metals and PCBs released from suspended sediments may reduce phytoplankton growth and cause some direct mortality. Impacts in summer are likely to be greatest near the thermocline where elevated concentrations of fine, potentially contaminated, sediments and dense

phytoplankton populations may occur. Diatoms, which are less tolerant of metals and PCBs than nanoplankton (Wolf et al 1982; O'Connors et al 1982), are most likely to be impacted.

Fine, low density, sediments can persist on the sea surface for some time after disposal (JRB 1984, Pequegnat 1978). Contaminants released from these sediments can become concentrated at the surface microlayer, where they may effect the phytoneuston. Elsewhere, phytoneuston adapted to polluted coastal waters have been shown to be quite tolerant to elevated contaminant (PAHs) levels (Riznyk et. al, 1987).

#### Zooplankton

As was the case for phytoplankton, zooplankton populations in Massachusetts Bay near the vicinity of MBDS are unlikely to be significantly affected by dredged material disposal. Adverse impacts will be confined largely to zooplankton damaged by shear stress and abrasion during disposal, and to those entrained within the dredged material convective jet.

Zooplankton entrained within the jet will be briefly exposed to elevated concentrations of suspended sediments. No studies have examined the effects of suspended sediments on any of the three predominant Massachusetts Bay copepod species. Studies of the neretic copepod, Acartia tonsa indicate that suspended sediment concentrations greater than 50 mg/l may reduce prey ingestion rates (see Stern and Stickle, 1978). For a typical disposal event at MBDS, the surface area likely to be impacted for a few hours by suspended solid concentrations greater than 50 mg/l is about 11 ha (see Table 4.C.2-1). Since this area represents an insignificant proportion of the total surface area of MBDS, no impacts on zooplankton populations outside the disposal site are anticipated.

Potentially toxic contaminants released from suspended sediments in the disposal plume may be directly absorbed by zooplankton, or indirectly taken up via contaminated prey (O'Connor et al. 1982). The significance of contaminant uptake by zooplankton during dredged material disposal has not been evaluated. Because of dilution however, it is highly unlikely that zooplankton outside of the immediate vicinity of the disposal operation will be impacted.

In summary, the disposal of dredged material at MBDS will not significantly impact the plankton populations of Massachusetts Bay. Localized (approximately 10-20 hectne) impacts on plankton of short (< four hours) duration may result from elevated concentrations of suspended solids. The elution of chemical contaminants in concentrations sufficient to impact plankton is unlikely, except possibly for localized impacts on phytoneuston and those entrained in the disposal plume.

#### 4.C.2. FINFISH AND SHELLFISH

As discussed in previous sections, the disposal of dredged material will alter the physio-chemical environment and benthic community structure at MBDS. Some of the consequences of disposal operations have the potential to exert short and/or longterm impacts on fisheries resources. Of greatest concern are impacts related to the temporary degradation of water quality, the deposition of contaminated sediments, and changes in benthic invertebrate (prey) communities.

##### Impacts to Fish Eggs and Larvae

Demersal eggs and larvae near the disposal point will be subject to direct burial by dredged material. Settling of resuspended sediments following disposal will subject additional eggs and larvae to siltation. All eggs and larvae subject to burial, and some fraction of those which experience siltation will be killed (cf. Sweeney 1978). At MBDS, the potential loss of demersal eggs is greatest during the fall and winter when the majority of demersal species are spawning eggs. Eggs of many of these species have prolonged incubation periods, and would be at a risk for a substantial period of time.

The substrate at MBDS in the vicinity of the disposal point is largely soft mud or dredged material. Relatively common species in the vicinity of MBDS likely to spawn on this type of substrate include snake-blenny and alligator fish. Species which spawn preferentially on hard or rocky substrate (e.g. Atlantic herring, American sandlance, and ocean pout) are not likely to deposit eggs at the disposal site. Although some spawning by these species may occur on hard bottom in the NE section of MBDS, this area will not be subject to significant siltation from disposal activities. Laboratory studies indicate that eggs spawned on fine substrates (e.g. winter flounder; see Baram *et al.*, 1976) may be less susceptible to siltation than those deposited on relatively coarse substrates (e.g. Atlantic herring; Messieh *et al.*, 1981).

Some plankton eggs and larvae will be entrained within the descending mass of water and dredged material (Truitt 1986) that forms following disposal. It is likely that many of these eggs and larvae would be damaged by shear forces or abrasion.

Elevated suspended sediment levels in the vicinity of the disposal site will probably cause little direct fish egg mortality. Concentrations of suspended sediments in the water column on the order of 200-1000 mg/l are likely following disposal (Morton and Paquette, 1985; Wright, 1978; Peddicord and McFarland, 1978). These levels will be quickly reduced by settling and dilution, and the ocean surface area containing high (>500 mg/l) concentrations will probably be less than 1.5 ha (see below). Short term exposure to suspended sediment concentrations of this magnitude are unlikely to cause direct mortality of fish eggs. Eggs of various anadromous and freshwater species appear tolerant of prolonged exposure to

high concentrations of suspended sediments (Stern and Stickle 1978; see JRB 1984; Schubel and Wang 1973). Hatching success of eggs of Atlantic herring, a marine species with demersal eggs, was unaffected by continuous exposure to concentrations in excess of 7000 mg/l (Messieh *et al.* 1981). Although caution is advised when extrapolating these results to marine species with planktonic eggs it seems likely that short term exposure to high suspended sediment concentrations at MBDS will result in little direct egg mortality.

Elevated suspended sediment levels during disposal may result in some direct mortality of planktonic larvae. Exposure to levels of 500 mg/l for 2-4 days elicit significant lethal effects in larval shad, yellow perch, and striped bass (see JRB 1984). Planktonic larvae at MBDS will be exposed to elevated concentrations for a much briefer period, but may be more sensitive to suspended sediments than those of freshwater or anadromous species.

Disposal of contaminated dredged material at MBDS may result in the release of some toxic substances into the water column (see Allen, and Hardy, 1980; Barr, 1987; Pequegnat, 1978). Although prolonged exposure to weakly diluted extracts from contaminated sediments can reduce survivorship of larval fish (Hoss *et al.*, 1974), concentrations of any toxins released from dredged material at MBDS would be quickly diluted below potentially lethal levels. Similarly, although disposal operations at MBDS may briefly reduce dissolved oxygen concentrations in the water column, no effect on planktonic fish eggs or larvae is expected because rapid dilution with oxygen rich waters will occur.

Although disposal activities at MBDS are likely to result in little direct mortality of planktonic fish eggs or larvae, it is possible that individual ichthyoplankters exposed to dredged material will suffer some negative effects over a longer period of time. The potential "sublethal" effects of natural and anthropogenic environmental stressors (e.g. toxic substances, reduced dissolved oxygen concentrations) on marine fish eggs and larvae are well documented (Rosenthal and Alderdice 1976). Stressors may elicit various adverse physiological, morphological, or behavioral responses. Ultimately the growth rate, survivorship, and the reproductive potential (fecundity) of the affected organisms may be reduced but given the limited spatial extent, no significant population level impacts would be expected.

Elevated suspended sediment levels can elicit sublethal responses in fish eggs and larvae. Prolonged exposure to suspended sediment concentrations of 100 mg/l slightly lengthened the incubation period of several anadromous and freshwater species (Schubel and Wang, 1973). The adhesive eggs of species used in these studies became coated with sediments, however, this work may be of limited relevance to marine species with planktonic (nonadhesive) eggs. Concentrations of suspended sediments greater than 3 mg/l have been noted to reduce the feeding success of Atlantic herring larvae (Messieh, 1981). Rosenthal (see Rosenthal and



Alderdice, 1976) found that suspended sediments (red clay) entrained by herring larvae blocked their gullets and prevented ingestion of captured prey. Swenson and Matson (1976) noted behavioral changes in lake herring exposed to moderate (26-28 mg/l) concentrations of red clay. Exposure durations at MBDS would not be anticipated to significantly impact the population composition.

Numerous toxic substances, including those likely to be released from dredged material, can elicit a variety of sublethal effects on fish eggs and larvae (Rosenthal and Alderdice, 1976; Rand and Petrocelli, 1985; Longwell and Hughes 1980). In general, the effects of any release of toxic substances from dredged material at MBDS should be minimal, and highly localized because of rapid dilution. Neustonic (near surface) eggs and larvae are probably most vulnerable since disposal operations can result in the formation of a surface slick of low density, organic material (JRB, 1984; Pequegnat, 1978). Neustonic ichthyoplankton drifting with the slick, could be exposed to elevated concentrations of hydrocarbons, organohalogens, and heavy metals if persistent for a prolonged period of time. During summer months at MBDS entrainment of suspended sediments at a thermocline might also lead to the prolonged exposure of some ichthyoplankton to contaminated suspended sediments. Morphological adaptations of larvae which aid floatation (i.e. oil globules, high surface/volume ratios; Bond, 1979) would tend to promote bioconcentration of toxins. Because phytoplankton and zooplankton are thought to readily accumulate toxins from the surface microlayer (Duce *et al.*, 1972), bioaccumulation of toxins via prey is also possible. Longwell and Hughes (1980) found significant correlations between various measures of mackerel egg health and hydrocarbon levels in plankton, and heavy metal levels in surface waters.

Although the effects of environmental stressors on fish eggs and larvae is well documented in the laboratory, little is known concerning population level responses in the field. If suspended sediments and toxins do impair rates of growth and development of larval fish, profound effects on larval mortality may occur. If for example, the daily mortality rate of fish larvae is 0.5, and exposure to suspended sediments were to lengthen the larval period for the entire population by one day, the total survival rate would be reduced by 50% due to this factor alone (see Wedemeyer *et al.*, 1984). Whether this impact has any ecological significance depends on the proportion of the population affected, and the compensatory action of density dependent population-level processes. All of which is dependent on the spatial and temporal persistence of the impact.

To further evaluate the importance of possible lethal and sublethal effects of disposal on ichthyoplankton, it is necessary to have some estimate of the ocean surface area that will be impacted by potentially significant (i.e. >ca 100 mg/l) concentrations of suspended sediments. The area impacted will depend on characteristics of the dredged material (i.e. sediment grain size, water content, volume), and conditions at MBDS at the time of disposal.

Assuming that 5% of dredged material remains in suspension, a conservative mixing model predicts that the ocean surface area impacted by >100 mg/l concentrations of suspended sediments at MBDS is 2.25 ha. (Table 4.C.2-1). This area represents <1% of the surface area at MBDS. The total ocean surface area impacted per year (based on 80 identical disposal events/year) would be 180 ha (or 0.7 square miles). Each episode would be undetectable after four hours and total occurrence represents 3.7% (approximately 14 days) of the year.

Overall, the potential impact of disposal operations on eggs and larvae will be greatest during late spring and summer when peak concentrations of ichthyoplankton are likely to occur. Disposal impacts during the fall and winter, and early spring will be largely confined to demersal eggs of a few species, and the planktonic larvae of American sand lance and Atlantic herring. Low water temperatures (and metabolic rates) during the winter and early spring will probably minimize the potential effects of suspended sediments and toxins during this time. In addition, sand lance larvae, which are predominant in winter and early spring, may be relatively tolerant of environmental stressors. Larvae are relatively large at hatching, and are apparently adapted to survive extended periods without food (Smigielski, et. al., 1984).

In summary, the total ocean surface area that will be impacted by significantly elevated concentrations of suspended sediments will represent only a very small fraction of the the range of any species likely to spawn, or be represented in the ichthyoplankton at MBDS. Most of the species likely to spawn in the vicinity of MBDS spawn over a wide area. Exceptions include silver hake and pollock which have relatively restricted, but still extensive, spawning grounds. All species likely to be represented in the ichthyoplankton at MBDS are widely distributed and common elsewhere in Massachusetts Bay and/or the Gulf of Maine. Even in the unlikely event that all eggs and larvae exposed to moderate concentrations of suspended sediments were killed, ocean disposal at MBDS would not have a significant impact on the marine resources of Massachusetts Bay or the Gulf of Maine.

#### Juvenile and Adult Fish

Mortality during disposal should be largely limited to those few fish that are entrained within, or buried by, the descending mass of dredged material. Even if dredged material is highly contaminated, short term increases in the concentration of chemical contaminants or suspended solids are unlikely to adversely affect substantial numbers of fish in the vicinity of the disposal point.

Laboratory studies generally indicate that adults and juveniles of freshwater, anadromous, and coastal species are tolerant of exposure to high concentrations of uncontaminated suspended sediments (Stern and Stickle, 1978; Peddicord and McFarland, 1978; Wakeman et. al. 1975). Mortality is related to the clogging of gills and subsequent respiratory

failure and has generally only been noted after prolonged exposure to concentrations above those likely to occur during disposal operations. In-situ studies at a disposal site in Chesapeake Bay using caged fish revealed no apparent effects (Flemer et al., 1968). Fish may, however, be much more sensitive to highly contaminated sediments. Juvenile striped bass suffered increased mortality after only several hours of exposure to contaminated sediments at a concentrations of 500 mg/l (Pedicord and McFarland, 1978). Various sublethal effects have also been attributed to elevated concentrations of suspended sediments (Sherk et al., 1975; Stern and Stickle, 1978).

Studies by Sherk et al. (1975) suggest that demersal species are more tolerant of suspended sediments relative to pelagic species. Demersal species are regularly exposed to elevated concentrations of sediments, and have probably evolved compensatory physiological or morphological adaptations (see Baram et al., 1976). Similarly, it is likely that estuarine and in general pelagic species of coastal areas are more tolerant of suspended solids than those characteristics of offshore waters. Juvenile fish are more susceptible, and less tolerant of gill clogging than adults (Sherk et al., 1975).

Most of the fish inhabiting MBDS are demersal or semidemersal, and thus are probably somewhat resistant to suspended sediments. Most of the remaining pelagic species (e.g. silver hake, Atlantic mackerel) are summer migrants to the Gulf of Maine and likely to be present at MBDS only during the late spring, summer, and fall. Also, pelagic species are highly mobile and able to avoid localized areas with high concentrations of suspended sediments (Johnston and Wildish, 1981; Wildish and Power, 1985; Messieh et al., 1981; see also Pequegnat, 1978; and Stern and Stickle, 1978). The threshold level to elicit avoidance behavior in juvenile Atlantic herring is 10 to 35 mg/l (Messieh et al., 1981), which would be limited to an area in the tens of hectares range at MBDS.

Sediments dredged from coastal waterways are frequently contaminated with a variety of substances toxic to fish and other organisms in long term exposure studies. Toxins likely to be present include heavy metals, chlorinated hydrocarbons (i.e. PCBs and DDT), and polycyclic aromatic hydrocarbons (PAHs). Although some contaminants (approximately 5%) may be eluted into the water column or remain in suspension, a large proportion will settle with the sediments in close proximity to the disposal point.

Demersal fish are exposed to contaminants by direct contact with sediments and interstitial water (cf Pequegnat, 1978), or from dietary sources. Exposure may result in bioaccumulation via bioconcentration (the passive diffusion of substances across gills or other epithelial tissues) or uptake from ingested materials (Kay, 1984; O'Connor and Pizza, 1984). Although the potential for bioaccumulation exists at MBDS, this study noted no significant uptake of heavy metals or PCBs in bivalves or crustaceans. Some accumulation of PCB and PAH compounds was evident at the disposal site in Neptys incisa but not in significant quantity. No

information is available concerning the bioaccumulation of contaminants in fish or MBDS. Given the mobile nature of most fish at MBDS and the general lack of significant uptake of contaminants by invertebrates at the disposal site (see Section 3.B.), elevated contaminant levels in fish seem unlikely. The potential for significant bioaccumulation at MBDS is probably greatest for relatively resident demersal species such as witch flounder, and those species feeding on Nephtys incisa (a polychaete worm which showed some evidence of PCB and PAH accumulation at the disposal site).

Degraded environmental conditions have been reported to result in elevated incidence of various diseases in finfish populations (Sindermann, 1979; Ziskowski, et al., 1987; Patton and Couch, 1984; Sonstegard and Leatherland, 1984). Fin erosion (fin rot), for example, has been associated with elevated concentrations of coliform bacteria, heavy metals, PCBs, oil, and other contaminants (Sindermann, 1979). Flatfish are liable to greater exposure to contaminated sediments than pelagic or semi-demersal species, and appear to have a higher incidence of abnormalities (Ziskowski et al. 1987). Uptake of pollutants (PCB's and PAH's) from ingestion of prey items (Nephtys spp) could potentially be a mechanism for trophic transfer. Based on limited sample size, Howe and Germano (1982) failed to detect an increased incidence of abnormalities in fish collected from two sites used for the disposal of contaminated material in Cape Cod Bay. Results of such field surveys of a limited geographical area are, however, undoubtedly biased by fish movement.

Disposal of dredged material will have only a minor affect on the feeding behavior or food resources of pelagic species. High suspended sediment concentrations may briefly curtail feeding by fish entrained in the disposal conjective jet plume. Disposal operations will probably result in short term reductions in prey (i.e. plankton) productivity (see Stern and Stickle, 1978; Barr, 1987). Any impact to primary or secondary production is however, likely to be highly localized, and ecologically insignificant to highly mobile planktivores.

Settling of dredged material at the disposal site will result in the temporary displacement of demersal fish, and the burial of prey resources. Although some immediate recolonization is possible, it is likely that biotic abundance, and perhaps diversity, will be reduced for a period of time following disposal (Durkin and Lipovsky, 1977). Recovery of the demersal fish community will be closely linked to the recovery of benthic invertebrate biomass and diversity. Frequent disposal operations in the vicinity of the disposal buoy will probably maintain an early successional benthic invertebrate community dominated by polychaetes. BRAT analysis (see Section 3.B.) suggests that the resulting demersal finfish community would be dominated by witch flounder and other fish capable to exploiting relatively small prey items. The relative abundance of large American plaice and other fish able to exploit prey more characteristic of undisturbed sites (e.g. larger echinoderms) would be reduced. Any effect

on the structure of the demersal fish community at the disposal site will, however, be highly localized and insignificant relative to the marine resources of Massachusetts Bay.

#### Shellfish and Other Invertebrate Resources

Disposal activities at MBDS will result in the burial, and likely mortality, of some benthic invertebrates of commercial importance. Pelagic invertebrates such as squid and shrimp will be subject to entrainment in the descending mass of dredged material and the disposal jet. Because marine crustaceans and molluscs are generally tolerant of exposure to high concentrations of suspended sediments for prolonged periods, it seems likely that short term exposure to elevated suspended sediment concentrations at MBDS will result in little mortality of adult crabs, lobsters or molluscs (Saila et al., 1972; Stern and Stickle, 1978).

As in the case of fish, larval crustaceans and molluscs are more sensitive to suspended sediments than adults. Larval lobsters are very sensitive of exposure to specific grain sizes of suspended sediments (see Barr, 1987). Although few lobsters larvae are present at MBDS, larvae of rock crab and jonah crab are likely to be present during the late spring and summer, and may be sensitive to suspended sediments.

The effects of disposal on lobsters are likely to be greatest during the late fall, spring, and early winter when, lobsters are presumably most abundant at MBDS. Effects of disposal on rock and jonah crabs is probably greatest during the spring or early summer when spawning and molting occurs (Williams, 1984). Long fin and short fin squid are seasonal migrants to Massachusetts Bay, and only likely to be abundant at MBDS during the summer. Although ocean quahog and sea scallop are present near or at MBDS, they are unlikely to be present in large numbers on dredged material or soft mud bottom in the vicinity of the disposal point.

#### Summary - Finfish and Shellfish

In general it appears that finfish and shellfish resources in the Gulf of Maine or Massachusetts Bay will not be significantly affected by the continued disposal of dredged material at MBDS. Adverse impacts to individual organisms will occur, but be insignificant outside the immediately vicinity of the disposal site. Similarly, any changes in community structure related to impacts on benthic food resources will be highly localized and insignificant to fisheries resources in the region.

Conservative impact estimates predict average annual elevations in suspended solid load ( $>100$  mg/l) to impact a total of 0.7 square miles for approximately a total of 14 days of the year. Chemical elution and subsequent water column dilutions, as discussed in Section 4B, are not expected to yield significant levels and in fact would only exceed the EPA Quality Criteria for water in a small percentage ( $<1\%$ ) of the MBDS water column. Sedimentary chemical contaminants are input to the site in

various concentrations (see Table 1-2) and are only found in low to moderate in-situ concentrations.

Although this study failed to demonstrate significant elevated concentrations of PCBs or other contaminants in most invertebrates at MBDS, the potential for bioaccumulation exists. It would be possible to restrict finfishing and shellfishing from within the disposal site, at least in the vicinity of the disposal buoy if significant contaminant residue levels are quantified, and to cap highly contaminated sediments. MBDS has an area of approximately 4.2 square miles, and represents an insignificant percentage of the total area available for ground fishing and shellfishing in Massachusetts Bay.

Even though continued disposal at MBDS will have no significant impacts to marine resources on a regional level, efforts will be made to minimize adverse affects at the disposal site. Managment consideration will be given to limiting disposal of highly contaminated dredged material (i.e. failing bioassay/bioaccumulation testing) and particularly fine grained contaminated sediments, during the spring, winter, and early fall if potential for significant impacts is evident. This policy would minimize potential impacts to the ichthyoplankton, summer pelagic migrants, and other marine organisms during peak periods of productivity. (Scheduling dredging operations during the fall, winter, and early spring also generally limit impacts to the recreational boating fleet and biota at the dredge site.) Although some species (e.g. Atlantic herring, American sandlance, and American lobster) could be more heavily impacted by disposal during later fall, winter and early spring, on balance use of MBDS during this period could be least damaging to marine biota, given these species' low densities on silty areas of MBDS.

Table 4.C.2-1. Required ocean surface area at MBDS to dilute the concentration of suspended sediments in a dredged material disposal plume to various threshold levels.

| % of Dredged Material<br>Settling at Point of<br>Disposal | Required Surface Area (ha) <sup>b</sup> |      |      |
|---|---|------|------|
|   | Concentration Threshold (mg/l)          |      |      |
|   | 10                                      | 100  | 500  |
| 0   | 450                                     | 45   | 9    |
| 50  | 225                                     | 22.5 | 4.5  |
| 95  | 22.5                                    | 2.25 | 0.45 |

<sup>a</sup>

calculations based on a simple model presented by JRB (1984) and the following assumptions:

1. all material not settling immediately at the disposal point remains in suspension for a sufficient period of time to allow dilution to threshold concentrations

2. no significant amount of bottom sediments are resuspended as a result of disposal operations
3. suspended sediments are uniformly distributed throughout the water column
4. average volume of dredged material disposed =  $3000 \text{ m}^3$
5. bulk density of dredged material =  $1200 \text{ kg/m}^3$
6. average water depth at MBDS = 80 m

b

Surface area of MBDS = 1078 ha (1 ha = 2.47 acres)

#### 4.C.3 ENVIRONMENTAL EFFECTS ON THE BENTHOS.

The Massachusetts Bay Disposal Site (MBDS) annually receives approximately 230,000 cubic yards of dredged material. Disposal at MBDS is likely to have a significant impact on the benthic community only at the point of disposal.

The disposal site has been used for dredged material and various waste disposal for a number of years. There appears to be evidence that stations sampled in the Massachusetts Bay have been altered to some degree by disposal operations. Gilberts study (Gilbert *et. al*, 1976) showed that although there was some similarity in the dominant species between samples at the disposal site and other samples from Stellwagen basin, the disposal area was characterized by lower abundances and diversity of organisms.

The process of disposing sediments buries the organisms inhabiting the site. This burial decimates the local populations of benthic organisms. Disposal operations can thus be thought of as an episodic disturbance to the benthic community. Recolonization of dredged material from larval recruitment and adult immigration is likely to be rapid. The pattern of recovery of benthic populations to this physical disturbance can be viewed in a successional context.

The existing paradigm for succession in soft-bottom benthic ecology is that early colonizing species facilitate colonization for later successional stages (Rhoads and Boyer, 1982). The initial colonizers are typically species with high dispersal capabilities, that are capable of rapid population increases (McCall, 1977). These early colonists rework the sediments through their feeding and burrowing activity. This biological mixing of the sediment substrate (bioturbation) homogenizes and oxygenates the upper few centimeters of the sediment, making the area favorable for later successional stages. Over time benthic community structure in the area will return to the pre-impact condition.

Benthic community structure will be also affected by the frequency of disturbance. Areas subject to frequent disturbances generally have low species diversity, characterized by high abundance of opportunistic species. An intermediate frequency of disturbance may enhance species diversity (Huston, 1979).

The effect of a recent disposal operation at MBDS can be assessed qualitatively by comparing the data collected at MBDS-ON station before and after disposal. The most obvious effect of dredged material disposal at MBDS is the decrease in the depth of the BMD (biogenic mixing depth). The region of shallow BMD's coincide with the distribution of dredged material at the disposal site, extremely shallow BMD depths are apparent on the recently disposed dredged material (Figure 3.A.2-46).

From the REMOTS photographs it can be seen that head down deposit feeders are wide spread in this area, indicating recolonization of the dredged material and vertical migration of adults from adjacent areas. This rapid infaunal recovery of much of the dredged material suggests that certain benthic taxa characteristic of the ambient silt-clay facies at MBDS are relatively resilient to disturbances caused by disposal operations. The heterogeneity in benthic community types observed in the REMOTS survey at this site may reflect the process of infaunal recolonization on the dredged material.

The Mud Station on dredged material had the highest density of individuals of all stations. This density can be attributed to high abundance and dominance by oligochantes at this station.

The number of species found at the Mud Station On Dredged Material was intermediate to that of the sand and mud stations.

As discussed above, the higher number of species at the Mud Station on dredged material over the other Mud Stations may be related to the frequency of disturbance.

Another hypothesis which might account for the high diversity and increased number of individuals is related to the substrate. The disposal of poorly sorted material provides a heterogeneous patchwork of substrate types, sand, silt and mud. This would allow many organisms with different substrate requirements to inhabit the area.

A cluster analysis was performed on all the data collected for MBDS using Bray-Curtis similarity index and group average sorting. This type of analysis can use all the information on abundances and species composition. Species which were found only in one sample were dropped from the analysis. The results of the analysis, similarity matrix and cluster diagram are presented in Figure 4.C.2-1.

The cluster analysis separates the data into three major groups, Mud stations (MBDS-REF, MBDS-OFF), Sand stations (MBDS-NES, MBDS-SRF) and Mud station impacted by the dredging operation (MBDS-ON). There is a clear separation between the sand stations and mud stations ( $s = 0.2170$ ). The sand station within MBDS clustered with the Sand Station outside of MBDS (MBDS-SRF), and the Mud Reference Station within MBDS (MBDS-REF) clustered with the Mud Reference Station outside of MBDS. This suggests that the impacts of dredged material disposal are not observable outside the immediate area of disposal (i.e. MBDS-ON).



The clustering pattern suggests that the Mud Station On Dredged Material is different from the other samples. Mud On station separated from the other Mud Stations at  $s = 0.2776$ . Presumably this reflects subtle differences in the benthic community caused by disposal impacts.

The most similar samples were the samples taken in September 1985 at the Mud Reference station (MBDS-REF) and Mud Station Off Dredged Material (MBDS-OFF) ( $s = 0.833$ ). The September Mud Reference Station (MBDS-REF) was more similar to the Mud Off station (MBDS-OFF) than to samples at the same station taken during the June and January cruises, suggesting a seasonal component that was picked up by the clustering algorithm. This community structure similarity suggests disposal impacts are not observable, at the benthic community level, outside of the immediate disposal site (MBDS-ON).

#### Summary - Benthos

In summary, the benthic community of the MBDS reference area (MBDS-REF) is similar to typical Massachusetts Bay and Stellwagen Basin species complex of Prionospio, Paraonis spp. and Thyasira sp. described by Gilbert (1976) and recent sampling by NMFS. Statistical analyses group the unimpacted sampling station (MBDS-OFF) within the disposal site with the reference area. There is a clear impact of dredged material disposal on the benthic community at the disposal site. MBDS-ON (the disposal point) was dominated by oligochaetes over Spio pettibonae. These organisms are the pioneers, or rapid recolonizers, of areas defaunated, and efficiently exploit substrate niches of high organic content. The summary statistics of densities (Appendix III) demonstrate the high oligochaete dominance and the 55 benthic species identified at MBDS-ON had an abundance of 26,548 per square meter. The reference area (MBDS-REF) benthic community was comprised of 35 species with a considerably lower density than the disposal point of 4,344 individuals per square meter. The area within MBDS, but not on disposed dredged material (MBDS-OFF) was similar in abundance to the reference site at 8,746 organisms per square meter from 35 species, differing predominantly in the presence of oligochaetes.

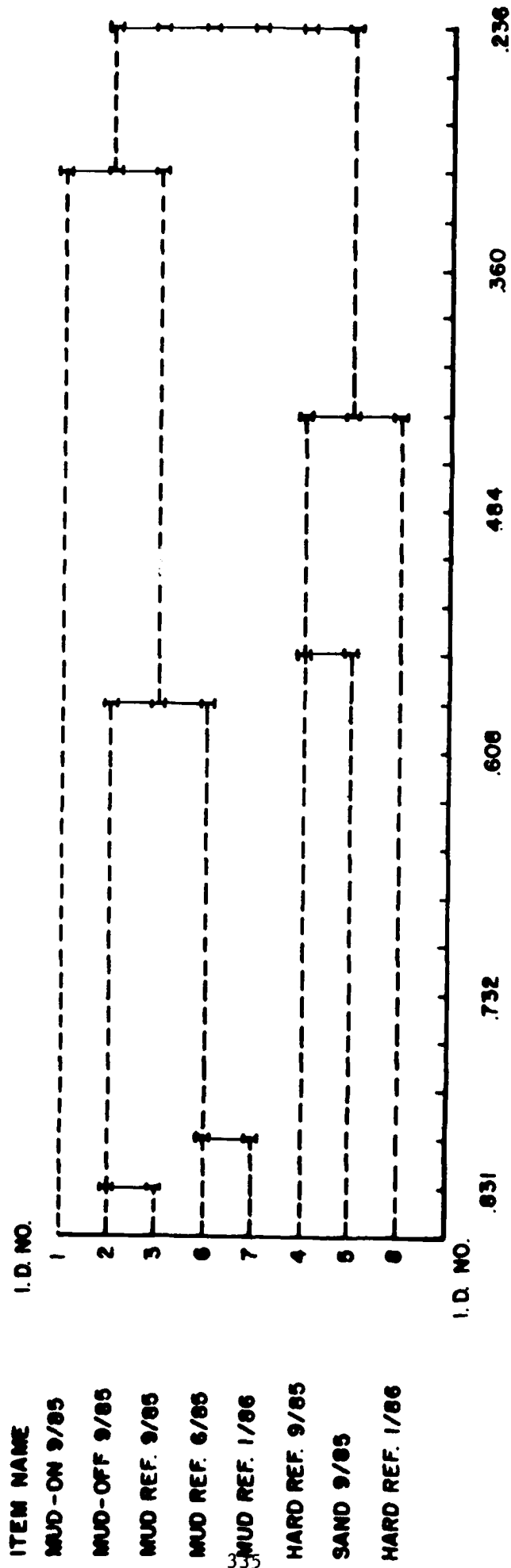


Figure 4.C.3-1  
Cluster Analysis of Benthic Data

#### 4.C.4. Effects on Mammals, Reptiles and Birds.

The limited spatial and temporal distribution of disposal impacts at MBDS have been documented through this site evaluation document. The effects of this activity on endangered species (cetaceans and turtles) are discussed in detail in section 4.C.5. The impacts of disposal on the dominant (non-endangered) marine mammals, i.e. the minke whale (Balaenoptera acutorostrata); the white sided dolphin (Lagenorhynchus acutus; and the harbor porpoise, Phocoena phocoena, as well as the subdominants (see Section 3.C.4.) would be correlated to habitat displacement and prey reduction. These two potential impacts would also be of concern for the dominant seabirds, i.e. the northern fulmar (Fulmarus glacialis; shearwaters (Puffinus spp.); storm petrels, Hydrobatidae; northern gannet (Sula bassanus); Pomarine Jaeger (Stercorarius pomarinus; gulls, Larinae; and alcids, Alcidae.

The distribution of physical impacts from approximately 80 disposal events per year, imparting elevated suspended solids concentrations for approximately four hours, is described as affecting approximately 10-20 hectares. (see Sections 3.A. and 4.C.1.). The chemical impacts from disposal of dredged material are primarily restricted to within the disposal site. Detailed evaluation of biological impacts to endangered cetaceans are discussed in the following section, but generally there are no anticipated, significant impacts to marine mammals, their habitat or prey.

Marine birds have a potential to be impacted by disposal of dredged material if their prey (pelagic fish and plankton) are at risk. Detailed evaluation of fisheries impacts (section 4.C.2) indicate no significant potential impacts to seabird prey could exist.

In summary, the disposal of dredged material at MBDS is not likely to significantly impact mammals, reptile and birds.

#### 4.C.5. Effects on Threatened and Endangered Species

No significant impacts of disposal activities on marine mammals and cetaceans in particular have been identified throughout this disposal site evaluation process. All physical, chemical, and biological effects of disposal activities are spatially confined to within the MBDS designated boundary (2 nautical mile diameter circle). The water column impacts are temporally of short duration and spatially restricted to a small percent of the MBDS 900,000 m<sup>3</sup> water column. Contaminant impacts to potential cetacean prey items are not anticipated since these species do not inhabit the deepwater silt/clay bottom of MBDS. Entrainment of planktivorous prey items during disposal is also anticipated to be minimal.

Humpback whales, Right whales and Finback whales have been identified as occurring in the vicinity of the disposal area. This area has been identified (Kenney, 1985) as a 90 to 95th percentile high cetacean use

area, with the 10 minute square east of MBDS in the >95th percentile (see Figure c.C.4-1). Some whalewatching activity often begins by the charter skipper heading east or southeast from MBDS disposal buoy approximately 6 km to Stellwagen Bank's northeast tip. The Bank itself is a sandy/cobble area 3.7 to 7.4 km wide and 25-35 meters deep extending 41 km to the southeast. The bank rises 60 meters upward of the Stellwagen Basin area. On the east side, the transition to the 80 meter depth is relatively steep. This rise or edge on the east side of the bank creates currents and eddies that bring nutrient rich cold, deep waters upward into the 30 meter photic zone. The Bank's substrate is ideal for certain cetacean prey items to inhabit. Notably, sand lance, Ammodytes americanus, which proliferate in and around Stellwagen Bank.

Sand lance are small schooling fish that are one of the alternative prey items of humpback whales. In order to assess anthropogenic impacts on this species, the National Marine Fisheries Service analyzed the organic residue levels of samples of sand lance from three different stations across the Bank during the Albatross 8109 cruise (Gadbois, 1982). The results of this study indicated low PCB contamination of sand lance (<0.1 ppm whole fish) and a slight (ppb) uniform level of PAH contamination throughout the Bank. These results indicate bay wide PCB influence and fossil fuel combustion impacts the entire Bank, without any noticeably detectable elevations of organic contaminants in areas of proximity, but 6 kilometers distant, to disposal activity at MBDS.

Current meter analyses (see Section 3.1) performed for this site evaluation study, did not describe significant vectors having a potential to transport contaminated dredged material to the Bank. A majority of flows, even during seasons of thermal stratification, are away from Stellwagen Bank. Bottom currents average only 3-5 cm/second, not strong enough to resuspend any contaminated sediments that might be present.

Water column impacts are minimal and well within the confines of MBDS boundary. As Section 4.B.1. described even in worst case analysis the large mixing volume and the relatively small amounts of contaminants would make violations of EPA water criteria unlikely. Physical impacts associated with suspended solids concentrations are largely restricted to the MBDS boundary water column even during periods of thermal stratification (see Section 4.A.1., 4.A.2, and 4.B.1).

Barge traffic is not likely impact or harass whales. Whales would be less impacted by disposal barges than by whale-watching vessels, who at least minimally, pursue the organisms.

Turtles, in general, are not likely to occur in the vicinity of MBDS due to its depth and substrate. Though loggerhead and leatherback turtles do have a low probability of occurrence. Of these species, leatherbacks, Dermochelys coriacea feed predominantly on jellyfish. The potential for entrainment of significant numbers of jellyfish due to disposal activity (approximately 80 events per year) is low, given the disposal entrainment

volume of 160,000 m<sup>3</sup> (17% of MBDS), available water column and short temporal persistence of entrainment impacts (minutes). Additionally jellyfish are seasonal in abundance and restricted to foraging in the upper water column. Other turtles prey items are not anticipated to occur in significant densities at the disposal point. In the northern and northeastern portion of MBDS the sandy/cobble substrate on the 60 meters isopleth may contain various turtle prey items, e.g. crabs, mussels, anemones etc.

Given the low numbers of turtles in the area and the presence of other similar foraging areas outside of the site disposal operations in the area is not likely to impact turtle populations.

#### Summary - Threatened and Endangered Species

In summary, the continued disposal of dredged material at MBDS is not likely to significantly impact threatened and endangered species, their prey, or their critical habitat. In particular, suspended solids and contaminant inputs to the water column do not have the potential to impact the water column beyond the immediate vicinity of disposal activity. Contaminant levels in prey species such as sand lance, Ammodytes dubius, are indicative of Massachusetts Bay-wide contamination. No evidence of significant contaminant remobilization exists with regard to dredged material disposal at MBDS. Turtle prey items, e.g. jellyfish, crabs etc., are also not anticipated to be significantly impacted due to their remoteness from the point of disposal and the limited spatial and temporal disposal impact persistence. Current vectors have not been identified as having the potential to transport contaminants to any significant endangered species critical habitat. Finally, the tug and barge activity would not be anticipated to interfere significantly with endangered species, given the organisms ability to avoid the traffic, and the minimal activity at MBDS in comparison to the nearby Boston Harbor traffic lanes.

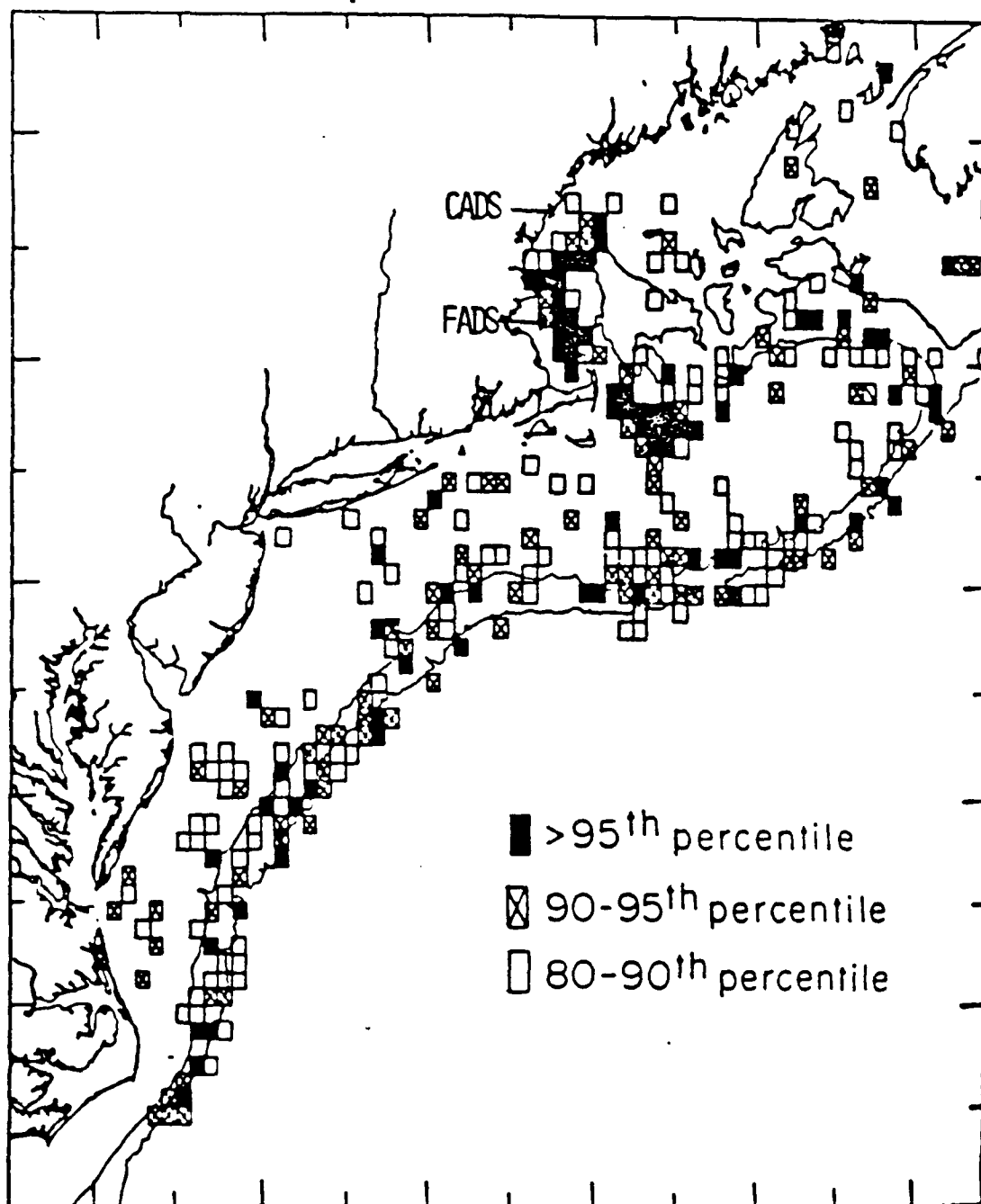


Figure 4.C.4-1 Map of the shelf waters of the eastern United States showing 10' blocks representing areas with a habitat-use index in the top 20% (adapted from Kenney 1985)

#### 4.D. Effects on Human Use

##### 4.D.1. Fishing Industry

According to the National Marine Fisheries Service (NMFS), the statistical area 514 surrounding the Massachusetts Bay Disposal Site (MBDS) is a relatively productive fishing area. According to NMFS statistics, it has about 5.7% of the total fish production capacity in the sixty statistical areas of the northeast (see Figure 3.D.1-1).

##### 4.D.1.a Short-term effects

The short-term effects of continued use of Massachusetts Bay Disposal Site on fishing will be minimal. At the present time, most fishing vessels tend to avoid the disposal site and conduct their operations in alternative locations. Fishermen operating within the site have, not unexpectedly, had their gear fouled by black mud. As a result, short-term effects on the continuation of this site as a disposal area will be the continuation of present regional fishing practices.

##### 4.D.1.b Long-term effects

Long-term effects of the Massachusetts Bay Disposal Site on fishing and other marine related activities are ambiguous. Based on estimates for a three year period provided by NMFS, it was determined that the maximum value of landings in the Massachusetts Bay Disposal Area was approximately \$20,000 per year, at most, for various species. The average number of pounds landed was 147,000 for the site (see Appendix III and text for actual pounds landed and their values for years 1982-1984). These estimates were based on the fact that the Massachusetts Bay Disposal Site is 0.6 of the 10 minute square longitude 42°25 and latitude 70°35.

The extended long-term effects are expected to be reduced landings. The number 147,000 pounds is at best a rough estimate of the number of pounds potentially harvestable from within MBDS. Given the assumption of uniform fishing effort over the entire area, it represents an upper limit. Also due to the migratory nature of fish, fish not caught in the MBDS may be caught elsewhere. Thus not fishing in MBDS may increase the value of surrounding areas, which would offset the loss in MBDS. In view of this, the loss in MBDS does not seem to have the potential to significantly (negatively) affect fishing as a regional industry.

##### 4.D.2. NAVIGATION

In accordance with the main channel servicing Boston Harbor, use of the Massachusetts Bay Disposal Site will not have any negative impacts on navigation either into or out of the harbor. The main channel servicing the harbor is southerly of the Massachusetts Bay Disposal Area and operations at MBDS are not expected to interfere with navigation. To

date, there are no future plans to expand the navigation channel that goes into Boston Harbor. Thus there are no foreseeable effects of the Massachusetts Bay Disposal Site on navigation into and out of Boston Harbor.

#### 4.D.3. MINERAL AND OTHER RESOURCES

Reports of the Mineral Management Service (MMS, 1983), U.S. Department of Interior indicated that there are no future plans for exploration or gas development in the Massachusetts Bay Disposal Site.

#### 4.D.4. GENERAL MARINE RECREATION

General marine recreation at this site, 15 miles offshore will most likely not be impacted by disposal operations. Barge traffic, fisheries impacts and substrate alternations are all not anticipated to be significantly affected by continued disposal at MBDS.

#### 4.D.5 HISTORIC RESOURCES

Continued use of MBDS will not impact any historic or archaeological resources.

Table 4.D-1 DETERMINATION OF FISH CATCH  
SIZE FOR THE  
MASSACHUSETTS BAY DISPOSAL SITE

LONGITUDE 42 25  
LATITUDE 70 35

| SPECIES          | 1982<br>POUNDS<br>LANDED | VALUE<br>LANDINGS | 1983<br>POUNDS<br>LANDED | VALUE<br>LANDINGS | 1984<br>POUNDS<br>LANDED | VALUE<br>LANDED |
|------------------|--------------------------|-------------------|--------------------------|-------------------|--------------------------|-----------------|
| COD (081)        | 257,079                  | \$87,892.65       | 525,526                  | \$183,893.47      | 90,511                   | \$34,268.50     |
| W FLOUNDER (120) | 89,768                   | \$37,529.39       | 100,134                  | \$ 44,314.27      | 75,904                   | \$49,636.65     |
| S FLOUNDER (121) | 0                        | \$ 0.00           | 2,480                    | \$ 1,801.91       | 0                        | \$ 0.00         |
| WITCH FL (122)   | 36,942                   | \$24,413.94       | 23,042                   | \$ 14,996.83      | 78,961                   | \$62,426.71     |
| YELLOWTAIL (123) | 80,970                   | \$44,077.26       | 132,741                  | \$ 69,927.42      | 20,655                   | \$14,894.55     |
| AM PLAICE (124)  | 27,791                   | \$12,829.93       | 142,310                  | \$ 66,987.26      | 67,960                   | \$43,841.54     |
| HADDOCK (147)    | 1,075                    | \$ 581.13         | 3,334                    | \$ 2,068.79       | 14,727                   | \$12,166.98     |
| RED HAKE (152)   | 0                        | \$ 0.00           | 42,250                   | \$ 3,686.74       | 58,813                   | \$ 4,314.44     |
| S HERRING (168)  | 0                        | \$ 0.00           | 19,038,872               | \$ 84,528.04      | 301,288                  | \$13,554.37     |
| MENHADEN (221)   | 2,524,097                | \$52,093.78       | 382,692                  | \$ 6,651.79       | 0                        | \$ 0.00         |
| POLLACK (269)    | 17,516                   | \$ 3,382.96       | 22,308                   | \$ 3,735.04       | .897                     | \$ 133.38       |
| DF SPINNY (352)  | 0                        | \$ 0.00           | 14,817                   | \$ 935.21         | 0                        | \$ 0.00         |
| S HAKE (509)     | 0                        | \$ 0.00           | 20,839                   | \$ 2,644.50       | 217,829                  | \$24,718.96     |
| WOLFFISH (512)   | 14,631                   | \$ 2,841.81       | 30,783                   | \$ 5,770.07       | 5,143                    | \$ 1,060.46     |
| LOBSTER (727)    | 0                        | \$ 0.00           | 0                        | \$ 0.00           | 1,125                    | \$ 2,857.44     |
| SHRIMP (736)     | 0                        | \$ 0.00           | 71,795                   | \$ 36,416.62      | 16,562                   | \$ 8,154.16     |
| B EYE TUNA (769) | 0                        | \$ 0.00           | 0                        | \$ 0.00           | 0                        | \$ 0.00         |
| S SCALLOPS (800) | 0                        | \$ 0.00           | 0                        | \$ 0.00           | 0                        | \$ 0.00         |
| TOTALS           | 3,049,929                | \$265,642.85      | 3,353,528                | \$528,348.96      | 950,925                  | \$272,028.14    |



| YEAR | TOTAL VALUE    |
|------|----------------|
| 1982 | \$265,642.85   |
| 1983 | \$528,348.96   |
| 1984 | \$272,028.14   |
|      | \$1,066,019.95 |

## 5. MANAGEMENT CONSIDERATIONS FOR THE DISPOSAL SITE

The management of the Massachusetts Bay Disposal Site is dependent on the buoy location, disposal methods, quality control of material disposed, monitoring and site capacity. Ultimately, these considerations are employed by NED in its DAMOS (Disposal Area Monitoring Systems) Management Plan.

### 5A Buoy Location

A primary consideration for managing MBDS as an ocean dredged material disposal site is to maintain the disposal buoy at given points for several years at a time. In situations where capping is required, a taut wire buoy, in conjunction with onboard disposal inspectors (see below) will maintain a point disposal, layering previous disposal episodes with the more recent ones. These techniques will serve to isolate contaminants and restrict the spatial extent of disposal impacts at MBDS. A low topographic relief mound would form at MBDS given close control of the disposal point (see Section 4A). The 100 meter depth at the point of disposal negates potential significant navigation, wave or current impacts from any topographic relief formed as the result of point disposal. The benefits of doing this affords a consistent burial impact at only one section of MBDS. Table 5-1 lists the theoretical ranges of mound height. Using the approximate three million cubic yards per decade calculated in Chapter 2, point disposal would allow formation of a 5 meter high mound within a 450 meter radius after approximately 4 years of buoy deployment at a particular location.

Limiting the spatial impact of disposal would be biologically advantageous since it maintains the benthic community in a pioneering or Stage I (Rhoads et al., 1979) community. These organisms are short-lived, potentially minimizing contaminant bioaccumulation and only biogenically rework the upper few centimeters of the substrate. This will allow isolation of contaminated dredged material in underlying strata.

### 5B Quality Control of Disposal Operation

The permitting of disposal of dredged material at MBDS by the Corps of Engineers is conducted under the authorities of Section 103 of the Marine Protection, Research and Sanctuaries Act of 1973. Each permit applicant is required to supply the Corps of Engineers with appropriate

testing of the dredged material to be disposed at MBDS. The general decision matrix is displayed in Figure 5A-1. The Federal dredging projects performed by the Corps also undergo this evaluation process before being disposed at MBDS. This evaluation may include bulk sediment testing, bioassay testing and bioaccumulation testing in accordance with the agreements in the joint EPA/COE (1977) handbook. Elutriate testing to predict disposal site impacts would usually not be performed because of the huge dilution zone available at MBDS (See Section 4.B.1). After bulk chemical and biological evaluation, material determined suitable, or to require capping is assigned a permit number and the volume and chemical characteristics are recorded for annual reporting to the United Nations International Maritime Organization under agreements of the London Dumping Convention. MBDS is continuously monitored to reevaluate this management process.

### 5C. Mitigation Measures

The actual disposal operation is monitored by New England Division for its precise location and method of disposal. The barges towed to MBDS have onboard inspectors under contract to NED that record the LORAN coordinates at which the barge stops and the distance to the buoy. This information is reported to NED for each activity as required in conditions of the applicants permit. Historically, disposal was from a moving barge which allowed a larger area to be impacted. Current permit requirements of point disposal in the presence of a NED inspector will minimize spatial impacts of disposal.

Other permit conditions may be required to mitigate impacts of disposal to biota. These potentially include seasonal restrictions of disposal activities, e.g. for highly contaminated material, capping, slack tide discharge, and habitat creation.

The majority of dredging occurs in winter months, to avoid summer boating activities. Consequently, disposal is predominantly in the winter months. This does however, allow winter/spring recruitment of benthic organisms onto the disposal mound. Biogenic mixing of the top 10-20 cm of sediment can be relatively intense throughout summer/fall. To minimize this potential pathway for contaminant remobilization, the point disposal of highly contaminated dredged material (i.e. failing bioassay/bioaccumulation testing) could be restricted to an early winter timeframe, followed by a capping or layering with cleaner material.

If potential impacts to the water in outside MBDS were to be identified, barge release could be : to slack tide. This would allow maximum settling time while minimizing particle transport by tidal currents.

The disposal of rock material could occur within MBDS on the northern and northeast section of cobbly substrate. This strategy will establish a reef like structure increasing habitat diversity. The cobbly northeast

section is generally 30 meters shallower and nearly two kilometers from the usual disposal point, minimizing contaminant interaction with the reef habitat.

Another mitigating factor is the evaluation each dredging project undergoes by NED personnel including: the project's disposal alternative based on environmental and economic considerations; the proposed method and time of dredging, environmental conditions at and near the proposed disposal site and the nature of the material to be dredged and the likelihood that it includes contaminants. (Dredged material has been deposited in the ocean, used for beach replenishment, trucked to landfills, used as the foundation for structures, or to create saltmarshes or islands, among other disposal options. The options available for a particular dredging project depend in part on the nature of the sediments.) These factors are thoroughly evaluated prior to deciding on ocean disposal at MBDS.

In characterizing the material to be dredged, many factors are considered, among them: potential routes of contamination to the dredging site -- e.g., natural drainage patterns in the area, the presence of any outfalls in the vicinity, and the area's hydrology; and previous or current sediment-test data for other Federal or nonfederal projects nearby; the extent of any historical or current industrial activity in or around the site; and any spills of oil or other substances that have occurred in the area.

Sampling and testing of the sediments to be dredged are typically performed with the location, depth, and method of sampling, as well as the method of testing, closely monitored. Grain-size analyses and bulk chemistry tests are required, as a minimum, in most cases. Elutriate and biological tests are also employed. Among the parameters routinely checked are volatile solids, water content, oil and grease, metals, and PCB's.

Each project is announced via a public notice that invites and typically allows 30 days for comments. Anyone who wishes to receive these notices will be added to the mailing list. All projects are also closely coordinated with the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service, all of whom receive sediment testing results. State concurrence in the form of State permits and coastal zone management certifications is required for the dredging (not disposal) action. As additional safeguards, the New England Division can impose special conditions on dredging projects; examples include restrictions on the type of dredging equipment used, capping, and a variety of conditions to assure accurate placement, if disposal in the ocean is allowed. Finally, NED's controls extend well beyond the issuance of the permit or the award of the dredging contract. All disposal in the ocean is inspected by an onboard Corps representative. Violators of permits have been and will continue to be subject to restitution and fines.

The Division also has the benefit of direct access to research performed by the Corps' Waterways Experiment Station (WES), including the findings of its five-year, nearly \$33 million Dredged Material Research Program and the ongoing Environmental Impacts Research Program, Environmental Effects of Dredging Program, and the Dredging Research Program. Some 70% of these program's research is performed by universities, firms, and institutions. The New England Division also works closely with WES on other dredging-related research, including the Field Verification Program, where the Division is a partner with WES and EPA in the research effort to evaluate (and improve if necessary) the predictive accuracy of the laboratory tests used in assessing material to be dredged.

In short, the New England Division has tried to establish a system of controls that accords careful attention to each phase of the process -- project evaluation, coordination, publicity, inspection, enforcement, scientific monitoring, and research. The system is comprehensive by design and incorporates many safeguards. The Division continually assesses its procedures in this area and welcomes ideas for refining them. One example of this is the 1985 DAMOS Symposium where, at the Division's request, over 100 scientists, regulators, and citizens contributed their thoughts on that program's techniques and approaches.

The monitoring of MBDS in itself allows a continued mitigation of impacts by adapting management strategies in response to impact evaluations.

The scientific monitoring of disposal activities at MBDS has been occurring since the area was first used for dredged material disposal. Physical, chemical, and biological sampling of MBDS throughout the last decade has allowed use of the area in a manner to minimize environmental impacts. Recent monitoring in 1985 to 1987 was performed as an evaluation of the environmental effects of disposal at this site, as summarized in this document.

Future monitoring of activities MBDS can now be directed toward a more detailed evaluation of those effects identified during the investigations reported in this document. The uptake of organic contaminants by the polychaete Nephtys incisa is an indication of potential trophic transfer of contaminants. Future monitoring will analyze this phenomena in Nephtys incisa and if elevated levels over sufficient spatial extent continue, the next trophic resident would be analyzed, i.e. the witch flounder. The Corps Federal dredging program and future permit evaluations will investigate the organic contamination of candidate material. A rationale will be developed for coinciding disposal of material with high levels of organic contamination (e.g. PAH, PCB) at a time of low biological activity and potentially concomitant with uncontaminated material. This will allow a capping or layering of material at the point of disposal, isolating the contaminated material from surficial biogenic activity. The residue levels of indigenous organisms will be monitored to identify future trends in contaminant mobility, while newly evolving

testing procedures for bioaccumulation testing, prior to disposal, will be implemented as methods are verified.

#### 5D. Monitoring Program - DAMOS

Monitoring of the disposal site will be conducted by the US Army Corps of Engineers and/or the US Environmental Protection Agency. The Corps of Engineers monitoring will be carried out through the New England Division's Disposal Area Monitoring System (DAMOS). Monitoring surveys will be conducted on a basis dependent on the volume and types of sediments disposed at the site and past study results, though a minimum of an annual survey cruise is probable over the next several years. Survey techniques used will, as appropriate, include those such as bathymetry, sediment profile camera studies, sediment chemistry, and contaminant uptake by members of the biological community at and around the site.

Monitoring will be directed at providing information to fulfill specific management questions and will entail an evolving program in response to advances in technology and results of prior study. The DAMOS program will be using a tiered approach to monitoring similar to that recommended by Fredette, et al. (1986). This tiered monitoring program for MBDS will be developed and periodically reviewed by NED in conjunction with a Technical Advisory Committee to DAMOS made up of nationally recognized experts.

Management questions to be addressed by the monitoring program will include those such as: are sediment mounds created at the site stable through time; are sediment contaminant levels at the site similar to levels expected based on the characterization of the disposed sediments; are contaminated sediments being dispersed from the site to areas of concern at levels and/or rates of concern.

#### 5E. Site Capacity

The available capacity of the MBDS is extremely large (Table 5-1). Projecting the average annual disposal volume of the last 12 years (233,000 cubic yards) over the next 50 and 100 years would provide disposal volumes of 11.7 and 23.3 million cubic yards of sediment. These disposal volumes, if spread evenly over the available area, would increase the height of the bottom approximately 0.8 and 1.6 meters, respectively. Creation of disposal mounds (typical heights at other sites of 5-10 meters) will provide for even greater disposal capacity far beyond these projections. Thus, the disposal site has sufficient capacity to meet any reasonable projection of long-term need.

#### 5F. Potential Post-Disposal Uses

Following closure of the disposal site at the end of its useful lifetime the site could potentially be used as fishery resource area. This use is possible through the beneficial creation of reef-like

structures from rock, cobble, or gravelly dredged material or the creation of disposal mounds from soft dredged material in configurations or slopes favorable to target species. The potential benefits of such sites to fishery resources are only just now beginning to be understood, though anecdotal evidence of increased fishery species usage does exist, and are presently being analyzed by the U.S. Army Corps of Engineers' Waterways Experiment Station.

#### Summary - Management Considerations

In summary, the intensive oceanographic evaluations performed at MBDS throughout this and previous studies will allow the New England Division to properly manage the site to minimize environmental impacts. In the near future, management requirements will be fulfilled by ongoing studies of contaminant mobility and evaluation of appropriate predisposal testing. As scientific understanding of oceanographic processes evolves, the management of MBDS will be continually reassessed for its comprehensive applicability.

Table 5-1. Thickness of the sediment deposit at MBDS  
Assuming even distribution of material within the site

| Thickness of<br>Dredged Material<br>(m) | Volume Disposed<br>(cubic yards) |
|---|----------------------------------|
| 0.25                                    | 3,530,824                        |
| 0.5                                     | 7,061,648                        |
| 0.75                                    | 10,592,472                       |
| 1                                       | 14,123,296                       |
| 1.5                                     | 21,184,944                       |
| 2                                       | 28,246,592                       |
| 3                                       | 42,369,887                       |
| 4                                       | 56,493,183                       |
| 5                                       | 70,616,479                       |
| 6                                       | 84,739,775                       |
| 7                                       | 98,863,070                       |
| 8                                       | 112,986,366                      |
| 9                                       | 127,109,662                      |
| 10                                      | 141,232,958                      |

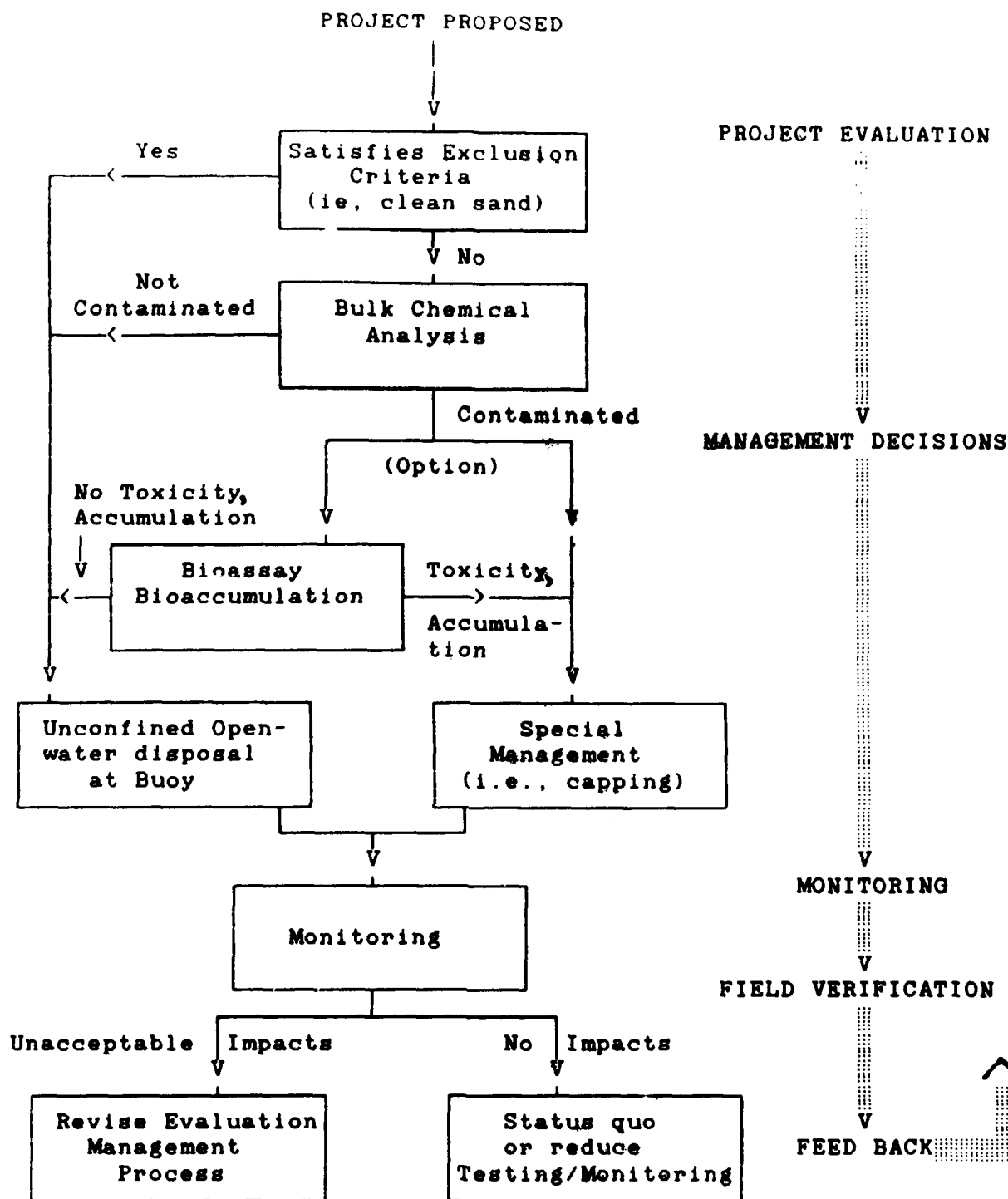


Figure 5A-1. Generic tiered decision protocol for open-water disposal of dredged material.

## 6. REFERENCES

- Acey, R., P. Healy, T.F. Unger, C.E. Ford and R.A. Hudson, 1987. Growth and aggregation behavior of representative phytoplankton as affected by the environmental contaminant Di-n-butyl Phthalate. *Bull. Environ. Contam. Toxicol.* 39:1-6.
- Ainley, D.G., and G.A. Sanger, 1979. Trophic relations of seabirds in the northeastern Pacific Ocean and Bering Sea. Pp. 95-122 in (J.C. Bartonak and D.N. Nettleship, eds.) *Conservation of Marine Birds of Northern North America*. U.S. Fish and Wildl. Serv., Wildl. Res. Rept. 11, Washington, D.C.
- Allen, G.M., 1916. The whalebone whales of New England. *Mem. Boston Soc. Nat. Hist.* 8:107-322.
- Allen, J.A. 1908. The North Atlantic right whale and its near allies. *Bull. Amer. Mus. Nat. Hist.* 24:277-329.
- Allen, K.O. and J.W. Hardy. 1980. Impacts of Navigational Dredging on Fish and Wildlife. *Bio. Ser. Prog. US FWS. FWS/OBS-80/07*
- Allen, K.R. 1971. A preliminary assessment of fin whale stocks off the Canadian Atlantic coast. *Rept. Int. Comm., Spec. Issue* 10.
- Amiard, J.C., C. Amiard-Triquet, B. Berthet and C. Metayer. *J. Exp. Mar. Biol. Ecol.* 106: 73-89.
- Anguillar, A. In press. A review of old basque shaling and its effect on the right whales of the North Atlantic. *Rept. Int. Comm., Spec. Issue* 10.
- Anthony, V.A. and G. Waring, 1980. The assessment and management of the Georges Bank herring fishery. *ICES Rapp. Proc.-Verb.*, 177:72-111.
- Arnold, P.W. and D.E. Gaskin, 1972. Sight records of right whales (*Eubalaena glacialis*) and finback whales (*Balaenoptera physalus*) from the lower Bay of Fundy. *J. Fish. Res. Bd. Canada* 29:1477-1748.
- Babcock, H.L. 1919. The turtles of New England. *Memoirs Boston Soc. National Hist.* 8:325-431.
- Balcomb, K.C. and G. Nichols, 1978. Western North Atlantic humpback whales. *Rep. Int. Whal. Comm.* 28:159-164.
- Baram, M. S., D. Rice, and W. Lee. 1976. *Marine Mining of the Continental Shelf, Legal, Technical and Environmental Considerations*. Ballinger Publishing Company, Cambridge, MA.



- Barr, Bradley W. 1987. Dredging Handbook - A primer for dredging in the coastal zone of Massachusetts. Massachusetts Coastal Zone Management Publication #14,870-181-500-6-87-CR.
- Beamish, P. 1981. Rare sighting of a right whale (Eubalaena glacialis). J. Ceta-Res. 2:2.
- Beck, B. 1983. The grey seal in Canada. Underwater World. Dept. of Fisheries and Oceans, Ottawa. 4 pp.
- Bent, A.C. 1921. Life histories of North American gulls and terns. U.S. Natl. Mus. Bull. 113: -345, Wash. D.C.
- Bent, A.C. 1922. Life histories of North American petrels and pelicans and their allies. U.S. Natl. Mus. Bull. 121:1-343, Wash. D.C.
- Bigelow, H.B. 1927. Physical Oceanography of the Gulf of Maine. Bull, U.S. Comm. Bur., 40:511-1027.
- Bigelow, H.B. and W.C. Schroeder 1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv., Fish. Bull. 53. 577 pp.
- Bleakney, J.S. 1965. Reports of marine turtles from New England and canadian waters. Canadian Field Nat. 79:120-128.
- BLM. 1977. OCS Sale No. 42. Draft EIS. Dept. of Interior.
- Boehm, P.D., W. Steinhauer, and J. Brown, 1984. Organic Pollutant Biogeochemistry Studies in the Northeast U.S. Marine Environment. Report to NOAA, Duxbury, MA. NMFS Contract No. NA-83-FA-C-00022.
- Bohlen, W.F. 1981. An Evaluation of the Causes of Shorefront Erosion: Castle Island, Boston, Massachusetts. Prepared for Fay, Spofford and Thorndike, Inc., Boston, MA 33 pps. and Illustrations.
- Bokuniewicz, H.J., J. Gebert, R.B. Gordon, J.L. Higin, P. Kaminsky, C.C. Pilbeam, M. Reed, and C. Tuttle, 1978. Field study of the mechanics of the placement of dredged material at open water disposal sites. Tech. Report D-78-7, U.S. Army Waterways Experiment Station.
- Bond, C.E. 1979. Biology of Fishes. Saunders.
- Bonrega, L.L., F. Arrabal, A. deVicente, I.F. Gomez, P. Ronco. 1983. Study of microbial inactivation in the marine environment. JWPCF 55:297-302
- Boston Edison Co. 1986. Marine Ecology Studies Related to Operation of the Pilgrim Station. Semi-annual Rep. No. 27. Boston, MA.

- Bothner, M.H., E.Y. Cambell, G.P. DiLisio, C.M. Paramenter, R.R. Rendigs, M.W. Doughten, R.G. Johnson, J.R. Gillison and N. Rait. 1986. Analysis of trace metals in bottom sediments in support of deepwater biological processes studies on the U.S. North Atlantic continental slope and rise. Outer Continental Shelf Study - MRS 86-0008. Minerals Management Service. U.S. Dept. of Interior.
- Boulva, J. and I.A. McLaren, 1979. Biology of the harbor seal, Phoca vitulina, in Eastern Canada. Bulletin of the Fisheries Research Board of Canada, No.200. 24 pp.
- Bourque, B. and M. Roberts, 1979. A summary and analysis of cultural resource information on the Continental Shelf from the Bay of Fundy to Cape Hatteras, Vol. III - Historic Ship. Institute for Conservation Archaeology, Peabody Museum, Harvard University Report 88. (Done for the Bureau of Land Management - Contract No. AA551-CT8-18).
- Bowman, R. E. and William L. Michaels, 1984. Food of seventeen species of northwest Atlantic fish. NOAA Tech. Men. NMFS - F/NEC-28 Woods Hole, Mass.
- Bowman, R.E. 1981. Stomach contents of twenty-four species of fish caught in Cape Cod Bay and/or Massachusetts Bay during the period 1972-1978.
- Braham, H.W. 1984. The Status of Endangered Whales: An Overview. Mar. Fish. Rev., Spec. Issue 46: 2-6.
- Brimley, H.H. 1931. Harbor seal in North Carolina. J. of Mammal 12:314.
- Brodie, P.F., D.D. Sameoto, and R.W. Sheldon, 1978. Population densities of euphausiids off Nova Scotia as indicated by net samples, whale stomach contents, and sonar. Limnol. Oceanogr. 23:1264-1267.
- Brown, R.F. and B.R. Mate, 1983. Abundance, movements, and feeding habits of harbor seal - Phoca vitulina, at Netarts and Tillamook Bays, Oregon. Fishery Bulletin 81:291-301.
- Brown, R.G.B., S.P. Barker, D.E. Gaskin, and M.R. Sanderman, 1981. The foods of Great and Sooty shearwaters Puffinus gravis and P. griseus in eastern Canadian waters. Ibis 123:19-30.
- Brown, R.G.B., D.N. Nettleship, P. Germain, C.E. Tull and T. Davis, 1975. Atlas of eastern Canadian seabirds. Canadian Wildl. Service, Information Canada, Ottawa. 220 pp.
- Brown, S.G. 1958. Whales observed in the Atlantic Ocean. Notes on their distribution. Mar. Obs. 28(181-182):142-146, 209-216.
- Brown, S.G. 1961. Observations of pilot whales (globicephala) in the North Atlantic Ocean. Norsk: Hvalfanst-tid. 50:225-254.

- Brown, W.S. and R.C. Beardsley, 1978. Winter Circulation in the Western Gulf of Maine: Part 1. Cooling and Watermass Formation. *J. Phys. Oceanogr.* 8(2):265-277.
- Brownawell, B.J. and J.W. Farrington. 1985 Partitioning of PCBs in marine sediments. In *Marine and Estuarine Geochemistry*, edited by A.C. Sigelo and A. Hattori.
- Bumpus, D.F. and L.M. Lauzier, 1965. Surface Circulation on the Continental Shelf of Eastern North America Between Newfoundland and Florida. *Am. Geograph. Soc., Serial Atlas of the Marine Environment*, Folio 7.
- Bumpus, D.F. 1974. Review of the physical Oceanography of Massachusetts Bay. Technical Report WHOI-74-8. Unpublished M.S. Woods Hole Oceanographic Institution, Woods Hole, MA.
- Bumpus, D.F. 1976. Review of the Physical Oceanography of Georges Bank. *Intl. Comm. Northwest Atlantic Fisheries. Res. Blu. No.* 12:119-134.
- Burghard, A. 1935. Whaling in Florida waters. *Florida Conservator* 1:4-5.
- Burnham, K.P., D.R. Anderson, and J.F. Laake, 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* No. 72. 202 pp.
- Butman, B. 1977. On the Dynamics of Shallow Water currents in Massachusetts Bay and on the New England Continental Shelf. Unpublished Manuscript. Report No. WHOI-77-15. Woods Hole Oceanographic Institution, Woods Hole, MA, 174 pp.
- Caldwell, D.K. and F.B. Golley, 1965. Marine Mammals from the coast of Georgia to Cape Hatteras. *J. Elisha Mitchell Sci. Soc.* 81:24-32.
- Caldwell, D.K. and M.C. Caldwell, 1966. Observations on the distribution, coloration, behavior and audible sound production of the spotted dolphin, Stenella plagiodon (Cope). *Los Angeles County Mus. Contrib. Sci.* 104:1-28.
- Caldwell, D.K., M.C. Caldwell and D.W. Rice, 1966. Behavior of the sperm whale. Pp. 677-717 In K.S. Norris (ed.) *Whales, dolphins, porpoises*. Univ. Calif. Press, Berkeley.
- Caldwell, D.K., M.C. Caldwell, 1969. The harbor seal, Phoca vitulina concolor, in Florida. *J. of Mammal* 50:379-380.
- Caldwell, D.K. and M.C. Caldwell, W.F. Rathjen, and J.R. Sullivan. 1971. Cetaceans from the Lesser Antillean Island of St. Vincent. *Fish. Bull.* 69:303-312.

- Caldwell, D.K. and M.C. Caldwell, 1975. Dolphin and small-whale fisheries of the Caribbean. J. Fish. Res. Bd. Canada 32:1105-1110.
- Carey, D.A. 1983. Particle resuspension in the benthic boundary layer induced by flow around polychaete tubes. Can. J. of Fish. and Aqu. Sci., Vol. 40: 301-308.
- Carr, A. 1952. Handbook of Turtles. Comstock Pub. Assoc., Ithaca, N.Y. pp 1-542.
- Carter, G.R., F.M. Fairfield, and H.E. Winn, 1981. Occurrence of beaked whales (Family Ziphiidae) in the western North Atlantic. Abstr. only, Fourth Biennial Conference on the Biology of Marine Mammals, 13-18-Dec., San Francisco, CA.
- Castello, H.P. and M.C. Pinedo, 1979. Southern right whales (Eubalaena australis) along the southern Brazilian coast. J. Mammal. 60:429-430.
- CETAP. 1982. A characterization of marine mammals and turtles in the mid- and north Atlantic areas of the U.S. outer continental shelf. Final Report of the Cetacean and Turtle Assessment Program, Bureau of Land Management, Contract No. AA551-CT8-48, U.S. Dept. of Interior, Wash. D.C. 450 pp.
- Charnov, E.L. 1976. Optimal Foraging: the Marginal Value Theorem. Theo. Pop. Bio. 9:129-136.
- Chu, K. 1986. Fin whale (Balaenoptera physalus). In T. French (ed.), Endangered, Threatened and Special Concern Vertebrate Species in Massachusetts. Mass, Div., Fish & Wildlife, Non-game and Endangered Species Program. Boston, MA 02202 (in press).
- Clarke, J.U. and A.B. Gibson, 1987. Regulatory identification of petroleum hydrocarbons in dredged material: Proceedings at a workshop. Miscellaneous Paper. D-87-3. U.S. Army Engineers Waterways Experiment Station, Vicksburg, Miss.
- Clay, A.M., T.R. Gilbert and G.C. McLeod, 1978. Critique and proposal for the management of dredged material in Massachusetts Bay waters. New England Aquarium, Boston, MA. - under NED contract DACW33-76-C-0096.
- Clayton, G., C. Cole, and S. Murawski. 1978. Common Marine Fishes of Coastal Massachusetts. Coop. Ext. Ser. Univ. MA. Amherst.
- Coastal Engineering Research Center, 1984. Shore Protection Manual. Fourth Edition. U.S. Army Corps of Engineers. Coastal Engineering Research Center. Waterways Experiment Station. Vicksburg, Miss. 2 Vols.

- COE, 1984. Environmental effects of dredging. U.S. Army Corps of Engineers, Info. Exchange Bull. Vol. D-84-2. May 1984. Pp 1-10.
- Cohen, E.B., M.D. Grosslein, M.P. Sissenwine, F. Steimle, and W.R. Wright, 1982. Energy budget of Georges Bank, p. 95-107 In M.C. Mercer (ed.) Multispecies approaches to fisheries management advice. Can. Spec. Publ. Fish. Aquat. Sci. 59.
- Cramp, S. (ed.), 1977. Handbook of the birds of Europe, the Middle East and North Africa. Vol.1, Ostrich - Ducks. Oxford Univ. Press, Oxford.
- Csanady, G.T. of 1974. Barotropic currents over the Continental Shelf. J. of Phys. Oceanogra. 4:357-371.
- Dailey, James - NOAA, Rockville, Maryland. Feb., 1988. Personal communication. Information from NOAA files concerning wrecks in MBDS.
- Davis, J.D. 1984. Western Cape Cod Bay: Hydrographic, Geological, Ecological and Meteorological Backgrounds for Environmental Studies. Pages 1-18 in Davis, J.D. and D. Merriman (eds.). Observations on the Ecology and Biology of Western Cape Cod, Massachusetts. Lecture Notes on Coastal and Estuarine Studies, Vol. 11. Springer-Verlag.
- Dillon, T.M. 1984. Biological Consequences of Bioaccumulation in Aquatic Animals: an Assessment of the Current Literature. TR D-84-2. U.S. Army Waterways Exper. Stat. Vicksburg, Miss.
- Doggett, L. and S. Sykes. 1980. Commercially important invertebrates. In An Ecological Characterization of Coastal Maine. S.I. Fefer and P.A. Schettig (P.I). US FWS. FWS/OBS-80/29.
- Donnelly, B.G. 1969. Further observations on the southern right whale, Eubalaena glacialis, in South African waters. J. Reprod. Fert. Suppl. 6:347-352.
- Duce, R.A., J.G. Quinn, C.E. Olney, S. R. Piotrowicz, B.J. Ray, and T.L. Wade. 1972. Enrichment of heavy metals and organic compounds in the surface microlayer of Narragansett Bay, Rhode Island. Sci. 176: 161-163.
- Durkin, J.T. and S.J. Lipovsky. 1977. Aquatic Disposal Field Investigations Columbia River Disposal Site, Oregon. Appendix E: Demersal fish and decapod shellfish studies. Tech. Rep. D-77-30. U.S. Army Waterways Exper. Stat. Vicksburg, Miss.
- Eberhardt, L.L. 1978. Transect methods for population studies. J. Wildl. Manage. 42:1-31.

- Eberhardt, L.L., D.G. Chapman, and J.R. Gilbert, 1979. A review of marine mammal census methods. Wildl. Monogr. No. 63. 46 pp.
- Eckman, J.E., A.R.M. Nowell and P.A. Jumars, 1981. Sediment destabilization by animal tubes. J. Mar. Res., 39: 361-374.
- Eckman, J.E. and A.R.M. Nowell, 1984. Boundary skin friction and sediment transport about an animal-tube mimic. Sediment., 31: 851-862.
- Edel, R.K., M. Cagan, J. H. Hain, P.W. Sorensen, 1981. Correlations between cetacean sightings and selected environmental variables. In A characterization of marine mammals and turtles in the mid- and North Atlantic areas of the U.S. outer Continental Shelf. Ann. rept. 1979, CETAP Program, Univ. of Rhode Island, prepared for Bureau of Land Mgmt., U.S. Dept. of Interior, Washington, D.C.
- Edwards, R (ed.), 1983. International Conf. of Justice case concerning delimitation of marine boundary in the Gulf of Maine area (Canada/USA), Vol.1, Dpp.1 Counter-Memorial. Marine Environment of the Gulf of Maine Area. Submitted USA, 28 June 1983.
- EPA, 1976. Quality Criteria for Water U.S. Environmental Protection Agency, Washington, D.C.
- Environmental Protection Agency, 1985. Health assessment document for inorganic arsenic. PB 84-190891 Research Triangle Park, NC.
- EPA, 1987. Update #2 to Quality Criteria for Water 1986. United States Environmental Protection Agency, Office of Water Regulations and Standards, Criteria and Standards Division. May 1, 1987, including Water Quality Criteria Summary.
- Estrella, B. T. Black Gill and Shell Disease in American Lobster as Indicators of Pollution In Massachusetts Bay and Buzzards Bay, Massachusetts. Publication# 14049-19-125-5-85-C.R. Commonwealth of Massachusetts.
- Evans, W.E. 1974. Radio-telemetric studies of two species of small odontocete cetaceans. In W.E. Schevill (ed.). The Whale Problem, A Status Report. Harvard Univ. Press, Cambridge, Mass.
- FAO. 1977. Report of the Advisory committee on Marine Resources Research Working Party on Marine Mammals. FAO Fisheries Rept. No. 194. FIR/R194 (En) Food and Agriculture Organization of the United Nations, Rome, Italy.
- Fisher, J. 1952. The Fulmar. Collins, St. James Place, London.
- Fitch, J.E. and R.L. Brownell, 1971. Fish otoliths in cetacean stomachs and their importance interpreting feeding habits. J. Fish. Res. Bd. Canada 25:2561-2574.

- Flemer, D.A., et al. 1968. Biological effects of spoil disposal in Chesapeake Bay. J. Sanit. Engin. Div. Roc. Am. Soc. Civ. Eng. 94: 683-706.
- Fredette, T.J., Anderson, G., Payne, B.S. and J.D. Lunz 1986. Biological Monitoring of Open-water Dredged Material Disposal Sites. Proc. of Oceans 1986. Marine Technology Soc. pp. 764-769.
- French, T. 1986. Endangered, Threatened and Special Concern Vertebrate Species in Massachusetts. Mass. Div., Fish & Wildlife, Non-game and Endangered Species Program. Boston, MA 02202 (in press).
- Fritts, T.H. and R.P. Reynolds, 1981. Pilot study of the marine mammals, birds and turtles in OCS areas of the Gulf of Mexico. U.S. Fish and Wildl. Serv. Office of biological Services, Washington, D.C. FWS/OBS-81/36.
- Furness, R.W. 1979. Foods of Great Skuas Catharacta skua at North Atlantic breeding localities. Ibis 121:86-92.
- Gadbois, D.F. 1982. Hydrocarbon analysis of targeted fin and shellfish species and sediments collected from northeastern U.S. coastal waters. U.S. Dept. of Commerce, N.O.A.A., NMFS, Northeast Fisheries Center Gloucester, MA 01930
- Gambell, R. 1972. Sperm whales off Durban. Disc. Rept. 35:199-358.
- Gaskin, D.E. 1968. The New Zealand Cetacea. Fish. Res. Bd.
- Gaskin, D.E. 1976. The evolution, zoogeography, and ecology of Cetacea. Oceanogr. Mar. Biol. Ann. Rev. 14:247-346.
- Gaskin, D.E. 1977. Harbour porpoise Phocoena phocoena (L.) in the western approaches to the Bay of Fundy 1969-75. Rep. Int. Whal. Comm.
- Gaskin, D.E. 1984. The harbour porpoise, Phocoena phocoena (L.): Regional populations, status, and information on direct and indirect catches. Rep. Int. Whal. Comm. 34:569-586.
- Gaskin, D.E., P.W. Arnold and B.A. Blair, 1974. Phocoena phocoena. Mamm. Species 42:1-8.
- Gaskin, D.E., G.J.D. Smith, and A.P. Watson, 1975. Preliminary study of movements of harbor porpoises (Phocoena phocoena) in the Bay of Fundy using radiotelemetry. Can. J. Zool. 53:1466-1471.
- Gaskin, D.E., K.I. Stonefield, P. Suda, and R. Frank, 1979. Changes in mercury levels in harbour porpoises from the Bay of Fundy, Canada, and adjacent waters during 1969-1977. Arch. Environ. Contam. Toxicol. 8:733-762.

- Gaskin, D.E. and A.P. Watson 1985. The harbor porpoise, Phocoena phocoena, in Fish Harbor, New Brunswick, Canada: occupancy, distribution, and movements. Fish. Bull. 83:427-441.
- Gilbert, T.R. 1975. Studies of the Massachusetts Bay Massachusetts Bay. Prepared for Commonwealth of Massachusetts, Division of Water Pollution Control. New England Aquarium, Boston, MA. 197 pps.
- Godin, A.J. 1977. Wild mammals of New England. Johns Hopkins Univ. Press, Baltimore, Md. 304 pp.
- Goerke, H., G. Eder, K. Weber and W. Ernst, 1979. Patterns of organochlorine residues in animals of different trophic levels from the Weser Estuary. Mar. Poll. Bull. 10:127-133.
- Gordon-Clark, J. 1976. Objectives for the management and conservation of marine mammals. FAO/ACCMR/MM/SC/123, Report to Mammals in the seas Conference, Bergen, Norway.
- Gould, P.J., C. Harrison, and D. Foresell, 1978. Distribution and abundance of marine birds - south and east Kodiak waters. In Environ. Assess. of the Alaskan Continental Shelf. Ann. Rept. 1978, Vol. II. U.S. Dept. of Commerce, and U.S. Dept. of Interior.
- Graham, J.J., S.B. Chenoweth, and C.W. Davis. Abundance, distribution, movements and length of larval herring along the western coast of the Gulf of Maine. Fish. Bull. 70: 299-305.
- Grant, W.D., L.F. Boyer and L.P. Sanford, 1982. The effects of bioturbation on the initiation of motion of intertidal sands. J. of Mar. Res. 40: 659-677.
- Grosslein, M.D. 1969. Groundfish survey programs of BCF Woods Hole. Comm. Fish. Rev. 31:22-35.
- Grosslein, M.D. and T.R. Azarovitz. 1982. Fish Distribution. New York Bight Atlas Monograph 15. New York State Seagrass Inst. Albany, N.Y.
- Grosslein, M.D., B.E. Brown, and R.C. Hennemuth, 1978. Research, assessment and management of a marine ecosystem in the Northwest Atlantic - a case study. Presented at Second Intern. ecol. congr. Satellite Progr. in stat. Ecol. Univ. of Parma, Inst. ecol., 70 pp.
- Grosslein, M.D., R.W. Langton, and M.P. Sissenwine, 1980. Recent fluctuations in pelagic fish stocks of the northwest Atlantic, Georges Bank region, in relation to species interactions, Rapp. P. - v. Reun. Cons. int. Explor. Mer., 177:374-404.



- Gunter, G. 1954. Mammals of the Gulf of Mexico. In P.S. Galtsoff (ed.) Gulf of Mexico; its origin, waters, and marine life. U.S. Fish Wildl. Serv., Fish. Bull. 89:543-551.
- Hain, J.H., G.R. Carter, S.D. Kraus, C.A. Mayo, H.E. Winn, 1982. Feeding behavior of the Humpback Whale Megaptera novaeangliae, in the western North Atlantic. Fish. Bull. 80:259-268.
- Hain, J.H., R.K. Edel, H.E. Hays, S.K. Katona, and J.D. Roanowicz, 1981. General distribution of cetaceans in the continental shelf waters of the northeastern United States. In A characterization of marine mammals and turtles in the Mid- and North Atlantic areas of the U.S. outer continental shelf. Ann. Rept. 1979, CETAP Program, Univ. of Rhode Island, prepared for Bureau of Land Mgmt. U.S. Dept. of Interior, Washington, D.C.
- Harris, D. L., 1972. Wave estimates for coastal regions in shelf sediment transport: Process and Pattern. D.J.P. Swift, D.B. Duane, O.H. Pilkey (Eds.). Dowden, Hutchinson and Ross Inc., Stroudsburg, PA. pp. 99-125.
- Hay, K. 1982. Aerial line-transect estimates of abundance of humpback, fin, and long-finned pilot whales in the Newfoundland-Labrador area. Rep. Int. Whales in the Newfoundland-Labrador area. Rep. Int. Whal. Comm. 32:475-485.
- Hay, K.A. 1985a. Status of the Humpback Whale, Megaptera novaengliae, in Canada. Can. Field Nat. 99:425-432.
- Hay, K.A. 1985b. Status of the Right Whale, Eubalaena glacialis in Canada. Can. Field Nat. 99:433-437
- Hayes, M.O., D.K. Hubbard and D.M. Fitzgerald, 1973. Investigation of erosion problems at Revere, Winthrop and Nantasket Beaches. Massachusetts Metropolitan District Commission, Commonwealth of Massachusetts Contract #2229.
- Hays, H.E., H.E. Winn, and R. Petricig, 1985. Anomalous feeding behavior of a Humpback Whale. J. Mamm. 66:819-821.
- Heinemann, D. 1981. A rangefinder for pelagic bird censusing. J. Wildl. Mgt. 45:489-493.
- Hjulstrom, F. 1935. Studies of the morpological activity of rivers as illustrated by the River Fyris: Upsala Univ. Geol. Inst. Bull. V 25:221-527.
- Hoese, H.D. 1971. Dolphin feeding out of water in a salt marsh. J. Mamm. 52:222-223.

- Holder, J.B. 1883. The Atlantic Right Whale. Bull. Am. Mus. Nat. Hist. 1:97-137.
- Horwood, J.W. 1976. On the joint exploitation of drill and whales. FAO/ACCMR/MM/SC/116. Report to Mammals in the Seas Conference, Bergen, Norway.
- Hoss, D.E., L.C. Coston, and W.E. Scharf. 1974. Effects of sea water extracts of sediments from Charleston Harbor, South Carolina, on larval estuarine fishes. Est. Coast. Mar. Sci. 2:323-328.
- Howe, A.B., T.P. Currier, S.L. Sass, and B.C. Kelly. 1984. Coastwide Fishery Resource Assessment: Massachusetts. Mass. Div. Marine Fish. Pub. no. 13639-130-70-6-84-CR.
- Howe, A.B., T.P. Currier, S.L. Sass, and B.C. Kelly. 1986. Coastwide Fishery Resource Assessment: Massachusetts. Mass. Div. Marine Fish. Pub. no. 14335-58-115-2-86-CR.
- Howe, A.B. and F.J. Germano, Jr. 1982. Fisheries and Environmental Baselines Relative to Dredge Spoil Disposal, Cape Cod Bay, 1981. Mass. Div. Mar. Fish. Rep.
- Hunt, G.L., G.A. Sanger, and B. Burgeson, 1981. Trophic relations of seabirds on the eastern Bering Sea, pp. 629-647. In D.W. Hood (ed.) The Bering Sea Shelf. Inst. of Mar. Sci., U. Alaska, Fairbanks.
- Huston, M. 1979. A general hypothesis of species diversity American Naturalist. 113:81-99.
- Johnson, A.C., P.F. Larsen, D.F. Gadbois and A.W. Humason, 1985. The distribution of Polycyclic Aromatic Hydrocarbons, in the surficial sediments of Penabsco Bay (Maine, U.S.A.) in relation to possible sources and to other sites worldwide. Mar. Env. Res. 15: 1-16.
- Johnson, B.H., 1978. Application of the instantaneous dump dredged material disposal model to the disposal of Stamford and New Haven Harbour material from a scow in Long Island Sound. Tech. Manuscript. U.S. Army Waterways Experiment Station.
- Johnston, D.W., and Wildish, D.J. 1981. Avoidance of dredge spoil by herring (Clupea harengus harengus). Bull. Envir. Cont. Tox. 26: 307-314.
- Jonsgard, A. 1966. The distribution of Balaenopteridae in the North Atlantic Ocean. Pp. 114-123 In Norris, K.S. (ed.) Whales, Dolphins, and Porpoises. Univ. Calif. Press, Berkeley.
- Jonsgard, A. 1982. The food of Minke Whales (Balaenoptera acutorostrata) in northern North Atlantic waters. Rep. Int. Whal. Comm. 32:259-269.

- Jonsgard, A. and K. darling, 1977. On the biology of the Eastern North Atlantic Sei Whale, Balaenoptera borealis Lesson. In Report of the Special Scientific Committee on Sei and Bryde's Whales, Rept. Int. Whal. Comm., Special Issue 1:124-129. Cambridge.
- JRB, 1984. An Assessment of the Potential Impacts on Zooplankton and Fish of Ocean Dredged Material Disposal at the Norfolk Disposal Site. Tech. Rep. prep. for EPA (Region III).
- Jumars, P.A. and A.R.M. Nowell, 1984. Fluid and sediment dynamic effects on marine benthic community structure. Amer. Zool. 24:45-55.
- Kapel, F.O. 1975. Preliminary notes on the occurrence and exploitation of smaller cetacea in Greenland. J. Fish. Res. Bd. Canada 32:1079-1082.
- Kapel, F.O. 1977. Catch of beluga, narwhals and harbor porpoises in Greenland, 1954-75, by year, month and region. Rept. Int. Whal. Comm. 27:507-520.
- Kapel, F.O. 1979. Exploitation of large whales in West Greenland in the twentieth century. Rep. Int. Whal. Comm. 29:197-214.
- Kapel, F.O. and F. Larsen, 1982. Whale sightings form a Norwegian small-type whaling vessel off West Greenland June-August 1980. Rep. Int. Whal. Comm. 32:521-530.
- Katona, S. 1976. Whales in the Gulf of Maine: 1975. Publ. privately. 39 pp.
- Katona, S.K., J.A. Beard and K.C. Balcomb, 1982. The Atlantic humpback fluke catalogue. Whale Watcher 16:3-8.
- Katona, S.K., J.A. Beard and K.C. Balcomb, III. 1984. The humpback whale fluke catalogue. Final rept. to NMFS contract No. NA-81-FA-C-00027.
- Katona, S., D. Richardson, and R. Hazard, 1975. A Field Guide to the Whales and Seals of the Gulf of Maine. Maine Coast Printers. 97 pp.
- Katona, S., W. Steiner, and H.E. Winn. 1977. Marine Mammals. Pp 1-167, In Center for Natural Areas, A summary and analysis of environmental information on the Continental Shelf from the Bay of Fundy to Cape Hatteras, 1977, Vol. 1, Book 2. Final Rept., Contr. No. AA550-CT6-45, Bureau of Land Mgmt., U.S. Dept. of Interior.
- Katona, S.K., P. Harcourt, J.S. Perkins, and S.D. Kraus, 1980. Humpback Whales: A catalog of individuals identified by fluke photographs. College of the Atlantic, Bar Harbor, Maine.

- Katona, S.K. and S. Kraus. 1979. Photographic identification of individual humpback whales (Megaptera novaeangliae) evaluation and analysis of the technique. Final Report to U.S. Marine Mammal Commission in fulfillment of Contract MM7AC015. 29 pp.
- Katona, S.K. and C.A. Mayo. 1986. Humpback Whale (Megaptera novaeangliae). In T. French (ed.). Endangered, threatened and special concern vertebrate species in Massachusetts. Mass. Div., Fish & Wildlife, Non-game and Endangered Species Program. Boston, MA 02202 (in press).
- Katona, S.K., V. Rough and D.T. Richardson, 1983. A Field guide to the whales, porpoises and seals of the Gulf of Maine and eastern Canada -- Cape Cod to Newfoundland. Scribner's Sons, New York. 255 pp.
- Katona, S.K., S.A. Testaverde. and B. Barr, 1978. Observations on a white-sided dolphin, Lagenorhynchus acutus, probably killed in gill nets in the Gulf of Maine. Fish. Bull. 76:475-476.
- Katona, S.K., H.P. Whitehead. 1981. Identifying Humpback Whales using their natural markings. Polar Record 20:439-444.
- Kay, S.H. 1984. Potential for Biomagnification of Contaminants Within Marine and Freshwater Food Webs. Tech. Rep. D-84-7. U.S. Army Waterways Exper. Stat. Vicksburg, Miss.
- Kellogg, R. 1929. What is known of the migrations of some whalebone whales. Smith. Inst. Ann. Report, 1928. Publ. 2981, pp. 467-494.
- Kenney, R.D. 1985. Where the whales and dolphins gather. Maritimes, Feb. 1985, p. 12-14.
- Kenney, R.D. 1986. Sei whale (Balaenoptera borealis). In T. French (ed.). Endangered, Threatened and Special Concern Vertebrate species in Massachusetts. Mass. Div., Fish & Wildlife, Non-game and Endangered Species Program. Boston, MA 02202 (in press).
- Kenney, R.D., D.R. Goodale, G.P. Scott, and H.E. Winn, 1981. Spatial and temporal distribution of Humpback Whales in the CETAP study area. In A characterization of marine mammals and turtles in the Mid- and North Atlantic areas of the U.S. outer continental shelf. Ann. Rept. 1979, CETAP Program, Univ. of Rhode Island. Prepared for Bureau of Land Mgmt., U.S. Dept. of Interior, Washington, D.C.
- Kenney, R.D., M.A. Hyman, and H.E. Winn, 1985. Calculation of standing stocks and energetic requirements of the cetaceans of the Northeast United States outer continental shelf. NOAA Tech. Memo. NMFS-F/NEC-41. 99 pp.

- Kenney, R.P. and G.P. Scott, 1981. Chapter III. Calibration of the Beechcraft AT-11 forward observation bubble for population estimation purposes. In A characterization of marine mammals and turtles in the Mid- and North-Atlantic areas of the U.S. outer continental shelf. Ann. Rept. 1979, for CETAP, Univ. of Rhode Island. BLM Ref. No. AA551-CT8-48. Wash. D.C.
- Klumov, S.K. 1962. The Right Whales (Balaenidae) of the Pacific Ocean. Trudy Inst. Okeanol. 58:202-297.
- Krasnow, L. 1978. Feeding energetics of the sooty shearwater (Puffinus griseus) in Monterey Bay. 3rd Ann. Symp. Field Studies in Calif., Calif. State Univ., Sacramento. Abstr.
- Kraus, S.D. 1985. A review of the status right whales (Eubalaena glacialis) in the western North Atlantic with a summary of research and management needs. Final report, Contract No. MM2910905. U.S. Marine Mammal Commission, Washington, D.C..
- Kraus, S.D. 1986. Black Right Whale (Eubalaena glacialis). In T. French (ed.). Endangered, Threatened and Special Concern Vertebrate Species in Massachusetts. Mass. Div., Fish & Wildlife, Non-game and Endangered Species Program. Boston, MA 02202 (in press).
- Kraus, S.D., and J.H. Prescott, 1981. Distribution, abundance and notes of the large cetaceans of the bay of Fundy, summer and fall 1980. Final Rept. to NMFS/NEFC, Contract No. NA-80-FA-2-00048.
- Kraus, S.D. and J.H. Prescott. 1982. The North Atlantic Right Whale (Eubalaena glacialis) in the Bay of Fundy, 1981, with notes on distribution, abundance, biology and behavior. Final Report to NMFS/NEFC Contract No. NA-81-FA-C-00030. 105 pp.
- Kraus, S.D., J.H. Prescott, P.V. Turnbull, and R.R. Reeves, 1982. Preliminary notes on the occurrence of the North Atlantic Right Whale, Eubalaena glacialis, in the Bay of Fundy. Rept. Int. Whale. Comm. 32:407-411.
- Kraus, S.D. and J.H. Prescott, 1983. A summary of 1982 research on the North Atlantic Right Whale Eubalaena glacialis with notes on seasonal distribution and abundance, and significant resightings of individuals. Annual Report to NMFS in fulfillment of Contract No. NA-81-FA-C-00030 and to the World Wildlife Fund-U.S. 39 pp.
- Kraus, S.D., J.H. Prescott, and G.S. Stone, 1983. Harbor Porpoise, Phocoena phocoena, in the U.S. coastal waters of the Gulf of Maine: A survey to determine seasonal distribution and abundance. Unpubl. Rept., New England Aquarium, Boston, MA. 15 pp.

- Kraus, S.D., J.H. Prescott and G.S. Stone, 1984. Right Whales (Eubalaena glacialis) in the western North Atlantic: A summary of research conducted from 1980 to 1984. Report to NMFS/NEFC, Contract No. NA-81-FA-C-88830, Woods Hole, Ma 02543.
- Krebs, J.R. and N.B. Davies, eds, 1978. Behavioral ecology: an evolutionary approach. Sinauer Associates, Sunderland, MA.
- Lake, J., G. Hoffman and S. Schimmel, 1985. Bioaccumulation of contaminants from Black Rock Harbor dredged material by mussels and polychaetes. Technical Report D-85-2, prepared by the U.S. Environmental Protection Agency, Environmental Research Laboratory, Narragansett, RI for the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.
- Langston, W.J. and M. Zhou, 1987. Cadmium accumulation distribution and elimination in the bivalve Macoma balthica: neither metallothionein nor metallothionein-like proteins are involved. Mar. Env. Res. 21:225-237.
- Larsen, P.F., D.F. Gadbois and A.C. Johnson, 1986. Polycyclic Aromatic Hydrocarbons in Gulf of Maine Sediments: Distributions and Mode of Transport. Mar. Env. Res. 18: 231-244.
- Larsen, P. F., V. Zdanowicz and A.C. Johnson, 1983. Trace metal distributions in surficial sediments of Penobscot Bay, Maine. Bull. Env. Contam. Toxicol. 31:566-573.
- Lavigne, D.M. 1980. Present status of northwest Atlantic Harp Seals, Pagophilus groenlandicus. Unpubl. ms., N.E. Endangered species Workshop. 8-11 May 1980, Provincetown, MA.
- Lazell, J.D. 1976. This Broken Archipelago. Quadrangle Press (Harper and Row), N.Y 260 pp.
- Lazell, J.D. 1980. New England waters: critical habitat for marine turtles. Copeia 1980:290-295.
- Leatherwood, S. 1975. Some observations of feeding behavior of Bottlenose Dolphins (Tursiops truncatus) in the northern Gulf of Mexico and (Tursiops cf. T. gilli) of southern California, Baja, California, and Nayarit, Mexico. Mar. Fish, Rev. 37:10-16.
- Leatherwood, S., D.K. Caldwell, and H.E. Winn, 1976. Whales, dolphins, and porpoises of the western North Atlantic. A guide to their identification. U.S. Dept. Commerce., NOAA Tech. Rept. NMFS circ. 396. 176 pp.
- Leatherwood, S., I.T. Show, R.R. Reeves, and M.B. Wright, 1982. Proposed modification of transect models to estimate population size from

- aircraft with obstructed downward visibility. Rep. Int. Whal. Comm. 32:577-580.
- Lien, J. and P. McLeod, 1980. Humpback collisions with fishing gear in Newfoundland: arbitration and education in a whale-fisherman dispute. Paper submitted to the N.E. Endangered Species Workshop, Provincetown, MA, 7-11 May, 1980.
- Lien, J. and B. Merdsoy, 1979. The Humpback is not over the hump. Nat. Hist. 88:46-49.
- Lipton, B. 1975. Whaling days in New Jersey. Newark Mus. Quart. 26:1-72.
- Lockwood, M., M.C. Gruntal, and W.R. Curtis. 1982 Side-Scan Sonar Survey of the Massachusetts Bay Low-Level Radioactive Waste Disposal Site. In: Marine Pollution, Papers, Oceans '82, Rockville, MD.
- Lockyer, C. 1981. Growth and energy budgets of large baleen whales from the Southern Hemisphere. Pp. 379-487 in FAO Advisory committee on Marine Resources Research, Working Party on Marine Mammals. Mammals in the sea, Volume III, general papers on large cetaceans. Food and Agriculture Organization of the United Nations, Rome.
- Longwell, A.C. and J.B. Hughes. 1980. Cytologic, cytogenetic, and developmental state of Atlantic mackerel eggs from sea surface waters of the New York Bight, and prospects for biological effects monitoring with ichthyoplankton. Rapp. Reun. Cons. Explor. Mer. 179: 275-291.
- Lunz, J.D. and D.R. Kendall. 1982. Benthic resources assessment technique, a method for quantifying the effects of benthic community changes on fish resources. In Marine Pollution Papers Oceans' 82. NOAA Office of Marine Pollution Assessment. pp. 1021-1027.
- Lux, F.E. and G.F. Kelly. 1978. Fisheries Resources of the Cape Cod and Massachusetts Bay Region. Nat. Mar. Fish. Ser. Northeast Fish. Center. Woodshole, MA.
- Lux, F.E. and G.F. Kelly. 1982. Abundance of Groundfish and Invertebrates in Otter Trawl Surveys of Offshore Waters of Massachusetts and Cape Cod Bays in 1975-1977.
- MacKintosh, N.A. 1965. The stocks of whales. Fishing News (Books), London. 232 pp.
- Malins, D.C., B.B. McCain, J.T. Landahl, M.S. Myers, M.M. Krahn, D.W. Brown, S-L Chan, and W.T. Roubal. 1988. Neoplastic and other diseases in fish in relation to toxic chemicals: an overview. Aquat. Tox. 11: 43-67.

- Marcuzzi, G., and G. Pilleri. 1971. On the zoogeography of cetacea. In Gioglio Pilleri (Ed.) Investigations on Cetacea, Vol. III:101-170.
- Maria, I.S., M. Gonzalez, W. Iara and A. Ober 1986. Arsenic levels in Chilean marine species. Bull. Envir. Contam. Toxicol. 37:593-598.
- Marshall, H.G. and M.S. Cohn. 1983. Distribution and composition of phytoplankton in northeastern coastal waters of the United States. Est. Coast. Shelf Sci. 17: 119-131.
- Marshall, H.G. and M.S. Cohn 1984. Phytoplankton distribution along the eastern coast of the U.S.A. in relation to abundance, composition, cell volume, seasonal, and regional assemblages. J. Plankton Res. 6: 169-193.
- Martin, C. and C.S. Yentsch. 1973. Monitoring the "Massachusetts Bay" Dumping Area in Massachusetts Bay for Effects of Dredge Spoil Disposal on phytoplankton growth. Cape Ann Society for Marine Sciences. Gloucester, MA
- Mass. D.W.P.C., 1978. Regulations for water quality certification for dredging, dredged material disposal and filling in waters of the Commonwealth. Massachusetts Department of Environmental Quality Engineering - Division of Water Pollution Control. 314 CMR 9.00.
- Mattews, L.H. 1937. Notes on the southern Right Whale, Eubalaena australis "Discovery" report 17:171-181.
- Mattila, D., P.J. Clapham, C.A. Mayo, S.K. Katona and G. Stone, 1985. Humpback whale studies on Silver Bank. Final Report. NMFS Contract No. 41 USC 525 (c)(3).
- May, R.M., J.R. Beddington, C.W. Clark, S.J. Holt, and R.M. Laws, 1979. Management of multispecies fisheries. Science (Wash. D.C.) 405:267-276.
- Mayo, C.A. 1982. Observations of cetaceans: Cape Cod Bay and Southern Stellwagen Bank Massachusetts 1975-1979. NTIS Report No. PB82-186263. 68 pp.
- Mayo, C., C. Carlson, P. Clapham, and D. Mattila, 1985a. Humpback Whales of the southern Gulf of Maine. Center for Coastal Studies, Provincetown, MA. Shank Painter Printing Co., Provincetown, MA. 62. pp.
- Mayo, C.A., C.A. Carlson, and M.K. Gilmore, 1985b. Food and feeding of Right Whales on Cape Cod Bay, Massachusetts. Presented at the Sixth Biennial Conference on the Biology of Marine Mammals, Vancouver, B.C., Nov. 22-26, 1985.



- MBO, 1987. Characterization of whale use of the Massachusetts Bay and Cape Arundel, Maine areas. Prepared by Manomet Bird Observatory in association with Sanford Ecological services under contract to NED via DACW-33-85-0001.
- McCall, P.L. 1977. Community pattern and adaptive strategies of the infaunal benthos of Long Island Sound. *Journal of Marine Research*. 35:221-266.
- McFarlane, R.W. 1963. Disorientation of loggerhead hatchlings by artificial road lighting. *Copeia* 1963L 153.
- Mead, J.G. 1975. Distribution of cetaceans along the Atlantic and Gulf coasts of the United States. Unpubl. ms. submitted to Marine Mammal Comm. MMC MM4AC007.
- Mead, J.G. 1977. Records of Sei and Bryde's Whales from the Atlantic coast of the United States, the Gulf of Mexico, and the Caribbean. In Report of the Special Scientific Committee on Sei and Bryde's whales. Rept. Int. Whal. Comm., Special Issue 1:113-116, Cambridge.
- Mead, J.G. In press. Twentieth century records of Right Whales (Eubalaena glacialis) in the Northwestern Atlantic Ocean. Rept. Int. Whal. Comm., Spec. Iss. 10.
- Mercer, M.C. 1967. Wintering of Pilot Whales, Globicephala melaena, in Newfoundland inshore waters. *J. Fish. Res. Bd. Canada* 24:2481-2484.
- Mercer, M.C. 1973. Observations on distribution and intraspecific variation in pigmentation patterns of odontocete cetacea in the western North Atlantic. *J. Fish. Res. Bd. Can.* 30:1111-1130.
- Mercer, M.C. 1975. Modified Leslie-DeLury population models of the Long-Finned Pilot Whale (Globicephala melaena) and annual production of the Short-Finned Squid (Illex illecebrosus) based upon their interaction at Newfoundland. *J. Fish. Res. Bd. Canada* 32:1145-1154.
- Mercer, S.N. 1985. Observations of cetaceans on Jeffrey's Ledge and in Ipswich Bay in spring, summer and autumn 1985 including references to previous seasons. Unpubl. rept.
- Mermoz, J.F. 1980. Preliminary report on the southern Right Whale in the southwestern Atlantic. Rept. Int. Whal. Comm. 30:183-186.
- Messieh, S.N., Wildish, D.J., and Peterson R.H. 1981. Possible Impact from Dredging and Spoil Disposal on the Miramichi Bay Herring Fishery. *Can. Tech. Rep. Fish. Aquat. Sci.* No. 1008
- Metcalf and Eddy, Inc. 1984. Applications for a waiver of secondary treatment for the Nut Island and Deer Island Treatment Plants. Commonwealth of Massachusetts. Vol. 1.

- Meyer, T.L., R.A. Cooper, and R.W. Langton 1979. Relative abundance, behavior and food habits of the American sandlance, Ammodytes americanus from the Gulf of Maine. Fish. Bull. 77:243-253.
- Michaels, W.L. and R.F. Bowman. 1983. Food of Seventeen Species of Northwest Atlantic Fish: Part II, Examination by year and listing of prey species. Woods Hole Lab. Ref. Doc. No. 82-17. NMFS Northeast Fisheries Center. Woods Hole, MA.
- Miller, D.S., P.M. Payne, and K.D. Powers 1980. Marine Observer Manual, App. B - A marine observer training program. Nat. Mar. Fish. Service, Northeast Fish. Center Contr. NA-80-FA-D-0004. 147 pp.
- Minerals Management Service (MMS) 1983. Proposed April 1984 North Atlantic outer continental shelf oil and gas lease offering. U.S. Dept. of the Interior. Washington, D.C. 620 pages, 9 Appendices, 5 maps.
- Mitchell, E. 1972. Assessments of northwest Atlantic Fin Whale stocks. Report of the International Commission on Whaling 22:111-118.
- Mitchell, E. 1973a. The Status of the World's Whales. Reprinted from Nature Canada 2:9-27, October/December 1973. Canadian Nature Federation, Ottawa, Canada.
- Mitchell, E. 1973b. Draft report on humpback whales taken under special scientific permit be Eastern Canadian land stations 1969-1971. Rept. Int. Whal. Comm. 23:138-154.
- Mitchell, E. 1974a. Present status of northwest Atlantic fin and other whale stocks. In W.E. Schevill (ed.) The whale Problem, A Status Report:108-169. Harvard Univ. Press, Cambridge, MA. 419 pp.
- Mitchell, E. 1974b. Trophic relationships and competition for food in the northwest Atlantic. P. 123-132, In Proc. Canad. Soc. Zool. Ann. Meeting, 2-5 June 1974.
- Mitchell, E. 1974c. Preliminary Report on Newfoundland fishery for Minke Whales (Balaenoptera acutorostrata). Rept. Int. Whal. Comm. 25:218-225.
- Mitchell, E. 1975a. Preliminary Report on Nova Scotia fishery for Sei Whales (Balaenoptera borealis). Rept. Int. Whal. Comm. 25:218-225.
- Mitchell, E. 1975b. Preliminary Report on Nova Scotia fishery for Sei Whales (Physeter catadon). Rept. Int. Whal. Comm. 25:226-235.
- Mitchell, E. 1975c. Porpoise, dolphin and small whale fisheries of the world. Status and problems. Int. Union Cons. Nat. Nat. Resource Monogr. No. 3, 129 pp.

- Mitchell, E. and D.G. Chapman, 1977. Preliminary Assessment of stocks of Northwest Atlantic Sei Whales (Balaenoptera boealis). In Report of the Special Meeting of the Scientific Committee on Sei and Bryde's Whales. Rept. Int. Whal. Comm. Special Issue 1:117-120, Cambridge.
- Mitchell, E. and R.R. Reeves 1983. Catch history, abundance and preset status of northwest Atlantic humpback whales. Rept. Int. Whal. Comm. (Special Issue 5):153-212.
- Mitchell, E. and V.M. Kozicki, 1984. Reproductive condition of male Sperm Whales, Physeter macrocephalus, taken off Nova Scotia. Reports of the International Whaling Commission, Special Issue 6:243-252.
- Moir, R. and M. Roberts, 1979. A summary and analysis of cultural resource information on the continental shelf from the Bay of Fundy to Cape Hatteras, Vol. I- Physical Environment. Institute for Conservation Archaeology, Peabody Museum, Harvard University Report 88. (Done for the Bureau of Land Management - Contract No. AA551-CT8-18)
- Moore, J.C. 1953. Distribution of marine mammals to Florida waters. Am. Midl. Nat. 49:117-158.
- Moore, J.C., and E. Clark 1963. Discovery of right whales in the Gulf of Mexico. Science 141:269.
- Morse, W.W., M.P. Fahay, and W.G. Smith. 1987. MARMAP Surveys of the Continental Shelf from Cape Hatteras, North Carolina, to Cape Sable, Nova Scotia (1977-1984). atlas No. 2. Annual Distribution Patterns of Fish Larvae. NOAA Tech. Memor. NMFS-F/NEC-47.
- Morton, R.W. 1983. Precision bathymetric study of dredged material capping experiment in Long Island Sound. In Wastes in the Ocean. D.R. Kester, B.H. Ketchum, I.W. Duedall and P.K. Park Eds. Wiley & Sons, New York, NY. pp 99-121.
- Morton, R.W. 1984. Dredged material disposal operations at the Boston Foul Ground, June 1982-Feb 1983. DAMOS Contribution #41. U.S. Army Corps of Engineers, New England Division. 28p.
- Morton, R.W. 1985. Disposal Area Monitoring System: Summary of program results, 1981-1984. Vol. I: Overview of the DAMOS program. DAMOS Contribution #46. U.S. Army Corps of Engineers, New England Division. 63p.
- Morton, R.W. 1986. Response to comments generated as a result of the DAMOS Symposium (January, 1985). DAMOS Contribution #56. U.S. Army Corps of Engineers, New England Division.

- Mullane, S.J. and A. Rivers, 1982. Mt. Desert Rock, Maine - Annual Report. Allied Whale, College of the Atlantic, Bar Harbor, Maine. 27 pp.
- Murray, A.J. and M.G. Norton. 1982. The field assessment of effects of dumping wastes at sea: 10 analysis of chemical residues in fish and shellfish from selected coastal regions around England and Wales, Fish Res. Tech. Rep. MAFF Direct. Fish. Res., Lowestoft (69) 42 pp.
- Muschenheim, D.K., J. Grant and E.L. Mills, 1986. Flumes for benthic ecologists: theory, construction and practice. In Mar. Ecol. Prog. Ser., Vol. 28: 185-196
- MWRA. 1987. Primary Productivity Program. Appendix Z from Vol. V. Secondary Treatment Facilities Plan. Boston Harbor Wastewater Conveyance System Boston, MA.
- MWRA, 1987. Draft Secondary Treatment Facilities Plan Volume V. - Massachusetts Water Resources Authority - November 17, 1987.
- National Climatic Data Center, 1986. Local climatological data: Portland, ME, 1985 annual summary with comparative data. U.S. Dept. of Commerce, Asheville, NC 28801. 7 pp.
- National Fish and Wildlife Laboratory, 1980a. Selected vertebrate endangered species of the seacoast of the United States: Green Sea Turtle. U.S. Fish. Wildl. Serv., Biol. Services Program. 6 pp.
- National Fish and Wildlife Laboratory, 1980b. Selected vertebrate endangered species of the seacoast of the United States: Kemp's (Atlantic) ridley Sea Turtle. U.S. Fish Wildl. Serv., Biol. Services Program. 6 pp.
- National Fish and Wildlife Laboratory, 1980c. Selected vertebrate endangered species of the seacoast of the United States: Leatherback Sea Turtle. U.S. Fish & Wildl. Serv., Biol. Services Program.
- Naval Underwater Systems Center (NUSC), 1979. DAMOS (Disposal Area Monitoring System) Annual Data Report - 1978, Supplement D. Massachusetts Bay Disposal Site. Newport, RI.
- Neave, D.J., and B.S. Wright, 1968. Seasonal migrations of the Harbor Porpoise (Phocoena phocoena) and other cetacea in the Bay of Fundy. J. Mamm. 49:259-264.
- Nettleship, D.N. 1972. Breeding success of the common puffin (Fratercula arctica l.) on different habitats at Great Island, Newfoundland. Ecol. Monogr. 42:239-268.

- Neumann, C.J., et al. 1978. Tropical cyclones of the North Atlantic Ocean, 1871-1977. U.S. Dept. of Commerce, NOAA, National Weather Service.
- Nishiwake, M. 1972. General Biology. In S.H. Ridgway (ed.) Mammals of the sea. C.C. Thomas Publ., Springfield, III. PP. 3-214.
- Nishiwaki, M. 1975. Ecological aspects of smaller cetaceans, with emphasis on the striped dolphin. J. Fish. Res. Bd. Canada 32:1069-1972.
- NMFS, 1985. Interagency coordination producing computer generated raw data from various North East Monitoring Program Stations NMFS - Woods Hole, Mass.
- NMFS. 1985. NMFS-NEFC cruises. Mimeo. (Jan.).
- NMFS. 1982. NMFS-NEFC survey cruises. Mimeo (Jan.).
- NMFS/NEFC. Woods Hole Lab. Ref. No. 81-14.
- NOAA. 1987. Status of Fishery Resources off the Northeastern United States for 1986. Tech. Memor. NMFS-F/NEC-43.
- Normandeau. 1985. Seabrook Environmental Studies, 1984. A characterization of Baseline Conditions in the Hampton-Seabrook Area, 1975-1984. Tech. Rep. XVI-II prep. for New Hampshire Yankee Division of Public Services Co. of N.H. Seabrook, N.H.
- Nowell, A.R., P.A. Jumars and R.F. Self. 1981. A Markov model of flow sediment-organism interactions: fluid mechanical and biological processes affecting the transition probabilities, in Proceedings International Geol. Cong. Conf., Nittrouer, Paris, France.
- O'Conner, J.M. 1984. Polychlorinated Biphenyl Transport in Coastal Marine Food Webs. EPA Env. Res. Lab. Gulf Breeze, Fla. EPA - 600/53-84-083.
- O'Connor, J.M. and J.C. Pizza. 1984. Eco-kinetic model for the accumulation of PCB in marine fishes. In Management of Bottom Sediments Containing Toxic Substances. Proc. 8th U.S./Japan Experts Meeting. T.R. Patin (ed.). U.S. Army CE. pp. 285-303.
- O'Connors, H.B.Jr., C.D. Powers, C.F. Wurster, K.D. Wyman, G.M. Nau-Ritter, and R.G. Rowland. 1982. Fates and biological effects on plankton of particle-sorbed PCB's in coastal waters. In Ecological stress and New York Bight. Science and Management. G.F. Myer (ed.). Est. Res. Fed. South Carolina. pp. 423-449.
- Omura, H. 1958. North Pacific Right Whale. Sci. septs, Whales Res. Inst. 13:1-52.

- Overholtz, W.J. and J.R. Nicolas, 1979. Apparent feeding by the fin whale, balaenoptera physalus and humpback whale, Megaptera novaeangliae on the American sandlance, Ammodytes americanus, in the Northwest Atlantic. Fish. Bull. 77:285-287.
- Padan, J.W., 1977. New England Offshore Mining Environmental Study (Project NOMES). NOAA Special Report. Pacific Marine Environmental Laboratory, Seattle, WA.
- Palmer, R.S. (ed.), 1962. Handbook of North American Birds. Vol. I. Yale Univ. Press, New Haven, Conn.
- Parker, B.B., and B.R. Pearce, 1973. The response of Massachusetts Bay to wind stress. MITSG Rep. No. 75-2, Cambridge, MA.
- Patton, J.S. and J.A. Couch. 1984. Can tissue anomalies that occur in marine fish implicate specific pollutant chemicals. In Concepts in Marine Pollution Measurements. H.H. white (ed.). Univ. Maryland. College Park. pp. 511-538.
- Paul, J.R. 1968. Risso's dolphin, Grampus griseus, in the Gulf of Mexico. J. Mamm. 49:746-748.
- Payne, K. and R. Payne, 1985. Large scale changes over 19 years in songs of humpback whales in Bermuda. Z. Tierpsychol. 68:89-114.
- Payne, K., P. Tyack, and R. Payne, 1983. Progressive changes in the songs of humpback whales (Megaptera novaeangliae). A detailed analysis to two seasons in Hawaii. Pp. 9-57 In R. Payne (ed.) Communication and Behavior of Whales. Westview Press, Inc. Boulder, CO.
- Payne, P.M., J.R. Nicolas, L. O'Brien, and K.D. Powers, 1986. Distribution of the humpback whale (Megaptera novaeangliae) on Georges Bank and in the Gulf of Maine in relation to densities of the sand eel (Ammodytes americanus). Fish. Bull: in press.
- Payne, P. M., K.D. Powers, and J.E. Bird, 1983. Opportunistic feeding on whale fat by Wilson's Storm-Petrels Oceanites oceanicus in the western North Atlantic. Wils. Bull. 95:478-479.
- Payne, P.M. and J.P. Ross, 1986. Loggerhead Turtle (Caretta caretta). In T. French (ed.). Endangered, threatened and special concern vertebrate species in Massachusetts. Mass. div. of Fisheries and Wildlife, Nongame and Endangered Species Program, Boston, MA 02202 (in press).
- Payne, P.M. and D.C. Schneider, 1984. Yearly changes in abundance of harbor seals, Phoca vitulina, at a winter haul-out site in Massachusetts. Fish. Bull. 82:440-442.

- Payne, P.M., L.A. Selzer, and A.T. Knowlton, 1984. Distribution and density of cetaceans, marine turtles and seabirds in the shelf waters of the northeastern United States. June 1980 - Dec. 1983, from shipboard observations. NMFS/NEFC Contr. No. NA-81-FA-C-00023. 246 pp.
- Payne, P.M., L.A. Selzer, P.W. Whan, and A.A. Whitman, 1985. The distribution, abundance, and selected prey of the harbor seal in Massachusetts and New Hampshire. Lab. Ref. Doc. No. 85:15, NMFS/NEFC, Woods Hole, MA 02543. 32 pp.
- Payne, R. 1976. At home with right whales. Nat. Geog. 149:322-339.
- Payne, R., O. Brazier, E.M. Dorsey, J.S. Perkins, V.J. Rowntree, and A. Titus, 1983. External features in southern right whales (Eubalaena australis) and their use in identifying individuals. Pp 371-445 In: R. Payne (ed.) Communion and Behavior of Whales. AAAS selected Symposium No. 76. Westview Pres, Boulder, Co.
- Peddicord, R.K. and V.A. McFarland. 1978. Effects of Suspended Dredged Material on Aquatic Animals. Tech. Rep. D-78-29. U.S. Army Waterways Exp. Stat. Vicksburg. Miss.
- Pequegnat, W.E. 1978. An Assessment of the Potential Impact of Dredged Material Disposal in the Open Ocean. Tech. Rep. D-78-2. U.S. Army Waterways Exp. Stat. Vicksburg. Miss.
- Perkins, J., and H. Whitehead, 1977. Observations on three species of baleen whales off northern Newfoundland and adjacent waters. J. Fish. Res. Bd. Can. 34:1436-1440.
- Perkins, J.S., K.C. Balcomb, III, G. Nichols, Jr., A.T. Hall, M. Smultea, and N. Thumser, 1985. Status of the west Greenland Humpback whale feeding aggregation, 1981-83. Rep. Int. Whal. Commn. 35:379-383.
- Perkins, J.S., and P.C. Beamish, 1979. Net entanglements of baleen whales in the inshore fishery of Newfoundland. J. Fish. Res. Bd. Canada 36:521-528.
- Perkins, J.S., and P.J. Bryant, G. Nichols, and D.R. Patten, 1982. Humpback whales (Megaptera novaeangliae) off the west coast of Greenland. Can. J. Zool. 60:2921-2930.
- Perrin, W.F., R.R. Warner, C.H. Fiscus, and D.B. Holts, 1973. Stomach contents of Porpoises, Stenella spp and yellowfin tuna Thunnus albacares in mixed species aggregations. Fish. Bull. 71:1077-1092.
- Pitcher, K.W. 1980a. Food of the harbor seal: Phoca vitulina richardsi in the Gulf of Alaska. Fish. Bull. 78:544-549.

- Pitcher, K.W. 1980b. Stomach contents and feces as indicators of harbor seal, Phoca vitulina, foods in the Gulf of Alaska. Fishery Bulletin 78:797-798.
- Powers, K.D. 1982a. Ecological coherence of Georges Bank to populations of marine birds. Report to NMFS/NEFC, unpublished, 26 pp.
- Powers K.D. 1982b. A comparison of two methods of counting birds at sea. J. Field Ornith. 53:209-222.
- Powers K.D. 1983. Pelagic distributions of marine birds off the northeastern United States. NOAA Tech. Memorandum NMFS-F/NEC-27. Woods Hole, MA. 199 pp.
- Powers, K.D., and E.H. Backus, 1981. The relationships of marine birds of oceanic fronts off the northeastern United States. D.O.E. Techn. Prog. Rept. (DOE Contract No. DE-AC02-78EV04706). Nov. 1981.
- Powers, K.D., and E.H. Backus. In press. Estimates of consumption by seabirds on Georges Bank. In R.H. Backus (ed.) Georges Bank and its surroundings. MIT Press, Cambridge, MA 02139.
- Powers, K.D., and R.G. Brown. In press. Bird life on Georges Bank to populations of cetaceans. Report to NMFS/NEFC, unpublished, 20 pp.
- Powers, K.D. and P.M. Payne, 1983. Distribution of marine mammals, birds and turtles near the Deepwater Dumpsite 106 (DWD-106) and the Philadelphia Dumpsite (PDS). In J.B. Pearce et al. (eds.) Northeast Monitoring Program, 106-Mile Site Characterization Update, NOAA Tech. Mem. NMFS-F/NEC-26, Chap. 11.
- Powers, K.D., P.M. Payne, and S.J. Fitch, 1982. Distribution of Cetaceans, Seabirds and Turtles, Cape Hatteras to Nova Scotia, June 1980-December 1981. Final Report to NMFS/NEFC Contract No. NA-81-FA-C-00023. 163 pp.
- Powers, K.D., P.M. Payne, and D.S. Miller, 1980. A marine observer training program. Final Rept. to NMFS/NEFC, Contract No. NA-80-FA-D-0004, Woods Hole, MA. 73 pp.
- Prescott, J.H., and P.M. Fiorelli, 1980. Review of the harbor porpoise (Phocoena phocoena) in the U.S. Northwest Atlantic. Final Rept. to Marine Mamm. Commission Contract No. MM8AC016, NTIS PB80-176928. 55 pp.
- Prescott, J.H., S.D. Kraus, P. Fiorelli, D.E. Gaskin, G.J.D. Smith, and M. Brander, 1981. Harbor porpoise (Phocoena phocoena) distribution, abundance, survey methodology and preliminary notes on habitual use and threats. Final Rept. to National Marine Fish. Service (NEFC), Contract No. NA-80-FA-D-00009.



- Prescott, R. 1986. Kemp's Ridley Sea Turtle (Lepisochelys kempi). In T. French (ed.). Endangered, threatened and special concern vertebrate species in Massachusetts. Mass. Div. of Fisheries and Wildlife, Nongame and Endangered Species Program, Boston, MA. 02202 (in press).
- Proni, J.K. 1976. Acoustic tracking of ocean-dumped sewage sludge. Science 193:1005-1007.
- Pruell, R.J. and J.G. Quiun, 1985. Geochemistry of organic contaminant, in Narragansett Bay Sediments. Est. Cstl. Shlf. Sei. 21: 295-312.
- Rae, B.B 1965. The food of the common porpoise (Phocoena phocoena). J. Zool. Lond. 146:114-122.
- Rand, G.M. and S.R. Petrocelli. 1985. Fundamentals of Aquatic Toxicology. Hemisphere Publ. Co. Wash.
- Raytheon, 1974. Massport Marine Deepwater Terminal Study: Site and Terminal Selection. Raytheon Company, Portsmouth, R.I. Prepared for the Massacahusetts Port Authority.
- Reese, J. R. and S. A. Chesser, 1985. Implementation of Corps/EPA Ocean Disposal Site Designation Gudiance at Yaquina Bay, Oregon. Environmental Effects of Dredging, Information Exchange Bulleting. October 1985. U.S. Army Corps of Engineers Waterways Experiment Station. Vicksburg, Mississippi.
- Reeves. R.R. 1975. The right whale. Conservationist 30:32-33, 45.
- Reeves, R.R. and R.L. Brownell, 1982. Baleen Whales Eubalaena gacialis and allies. Pp 415-444 In J.A. Chapman and G.A. Feldhamer (eds.) Wild Mammals of North America. Biology, Management and Economics. Johns Hopkins Univ. Press, Baltimore. 1147 pp.
- Reeves, R.R., S. Kraus, and P. Turnbull, 1983. Right whale refuge? Nat. His. 92:40-45.
- Reeves, R.R., J.G. Mead, and S. Katona, 1978. The right whale, Eubalaena glacialis in the western North Atlantic. Rep. Int. Whal. Comm. 28:303-312.
- Rhoads, D.C., J.Y. Yingst and W. Ullman, 1978. Seafloor stability in central Long Island Sound: Pt. 1: Temporal changes in erodibility of fine-grained sediment, in Estuarine Interactions, M.L. Wiley, ed., Academic Press, 221-244.
- Rhoads, D.C. and L.F. Boyer, 1982. The effects of marine benthos on physical properties of sediments: a successional perspective. In Animal-Sediment Relations, P.L. McCall and M.J. Tevesz (Eds.). Plenum Press, New York, NY. pp. 3-15.

- Richardson, D., S.K. Katona, and K. Darling, 1974. Marine Mammals pp. 9-37 of Chapter 14 In TGIGOM (The research institute of the Gulf of Maine). A socio-economic and environmental inventory of the North Atlantic region, Sandy Hook to Bay of Fundy. V.l.(4) Bureau of Land Mgt. Marine Minerals Div. Contract #08550-CT3-8.
- Riser, N.W. and C.M. Jankowski, 1974. Physical, chemical, biological and oceanographic factors relating to disposal of dredged material in Massachusetts Bay - Phase I. Northeastern University, Marine Science Institute, Nahant, MA.
- Riznyk, R.Z., J.T. Hardy, W. Pearson, and L. Jabs. 1987. Short-term effects of polynuclear aromatic hydrocarbons on sea-surface microlayer phytoneuston. Bull. Environ. Contam. Toxicol. 38: 1037-1043.
- Rosenthal, H. and D.F. Alderdice. 1976. Sublethal effects of environmental stressors, natural and pollutional on marine fish eggs and larvae. J. Fish. Res. Board Can. 33: 2047-2065.
- Ross, J.P. 1986. Leatherback Turtle (Dermochelys carriacea). In T. French (ed.). Endangered, threatened and special concern vertebrate species in Massachusetts. Mass. Div. of Fisheries and Wildlife, Nongame and Endangered Species Program, Boston, MA. 02202 (in press).
- Rowlett, R.A. 1980. Observations of marine birds and mammals in the northern Chesapeake Bight. U.S. Fish Wildl. Serv., Biol. Serv. Progr. FWS/OBS-80/04.
- Rubinstein, N.I., E. Lores and N. Gregory. 1983. Accumulation of PCBs, mercury and cadmium by Nereis virens, Mercenaria mercenaria and Palaemopotes pugio from contaminated harbor sediments. Technical Report D-83-4. Prepared by U.S. Environmental Protection Agency, Gulf Breeze, Fla. for the U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- Saemundsson, B. 1939. Zoology of Iceland. Muntsgaard. Copenhagen.
- S.A.I.C., 1987. FADS Site Designation Study Data Report. Volumes I to III. Science Applications International Corporation. Contract DACW33-86-D-0004 to New England Division, Corps of Engineers.
- Sailia, S.B., S.D. Pratt, T.T. Polgar. 1972. Dredge Spoil Disposal in Rhode Island Sound. Mar. Tech. Rep. No. 2. U. Rhode Island. Kingston.
- Scammon, C.M. 1874. The marine mammals of the North-western coast of North America. Dover Publ., New York, NY.
- Schevill, C.M. 1956. Lagenorhynchus acutus off Cape Cod. J. Mammal. 27:128-129.

- Schevill, W.E., and R.H. Backus, 1960. Daily patrol of a Megaptera. J. of Mamm. 41:279-281.
- Schevill, W.E., K.E. Moore, and W.E. Watkins. 1981. Right Whale, Eubalena glacialis, sightings in Cape Cod waters. Woods Hole Ocean. Inst. Tech. Rept. WHOI-81-50, Woods Hole, MA. 16 pp.
- Schimidly, D.J. 1981. Marine mammals of the southeastern United States coast and the Gulf of Mexico. U.S. Fish and Wildl. Service, Biol. Serv. Progr. FWS/OBS-80/41.
- Schlee, J., D.W. Folger, and C.J. O'Hara, 1973. Bottom sediments on the Continental Shelf off the Northeastern United States - Cape Cod to Cape Ann, Massachusetts. U.S. Geological Survey. Misc. geological Investigations Map 1-746. U.S.G.S. Washington, DC.
- Schoener, T.W. 1971. Theory of feeding strategies. Annual Rev. Ecol. Syst. 2:369-404.
- Schubel, J.R. and J.C.S. Wang. 1973. The Effects of Suspended Sediment on the Hatching Success of Perca flavescens (Yellow Perch), Morone americana (White Perch), Monroe saxatilis (Striped Bass), and Alosa pseudoharengus (Alewife) Eggs. Chesapeake Bay Inst. Spec. Rep. 30. Ref. 73-3.
- Schubel, J.R. and J.C.S. Wang. 1973. The Effects of Suspended Sediment on the Hatching Success of Perca flavescens (Yellow Perch), Morone americana (White Perch), Monroe saxatilis (Striped Bass), and Alosa pseudoharengus (Alewife) Eggs. Chesapeake Bay Inst. Spec. Rep. 30. Ref. 73-3.
- Schurman, V.R. 1983. Report on Nantucket grey seals, winter and spring 1983. NMFS/NEFC Contract No. NA-83-FB-A-00075.
- Schurman, V.R. 1986. Gray Seal (Halichoerus grypus). In T. French (ed.) Endangered, threatened and special concern vertebrate species in Massachusetts. Mass. Div. of Fisheries and Wildlife, Nongame and Endangered Species Program, Boston MA. 02202 (in press).
- Schwartz, J.P. 1987. PCB concentrations in marine fish and shellfish from Boston and Salem Harbors, and coastal Massachusetts. Mass. Div. Mar. Fish. Cat Cove Marine Laboratory. Publication #14,997-36-110-8-87-CR.
- Science Applications, Inc. (SAI), 1985 Summary of Program Results 1981-1984 DAMOS. Newport, RI.
- Scott, G.P. and J.R. Gilbert, 1982. Problems and Progress in the U.S. BLM-sponsored CETAP surveys. Rep. Int. Whal. Comm. 32:587-600.

- Scott, G.P., R.D. Kenney, J.G. Gilbert, and R.K. Edel, 1981. Estimates of cetacean and turtle abundance in the CETAP study area with an analysis of factors affecting them. In A characterization of marine mammals and turtles in the Mid- and North Atlantic areas of the U.S. outer Continental Shelf. Ann. Rept. 1979, CETAP Program, Univ. of Rhode Island, prepared for Bureau of Land Mgmt., U.S. Dept. of Interior, Washington, D.C.
- Scott, G.P., R.D. Kenney, T.J. Thompson, and H.E. Winn, 1983. Functional roles and ecological impacts of the cetacean community in the waters of the northeastern U.S. continental shelf. Int. Cons. Explor. Sea., C.M. 1983/N:12.
- Scott, G.P., and H.E. Winn, 1980. Comparative evaluation of aerial and shipboard sampling techniques for estimating the abundance of Humpback Whales (Megaptera novaeangliae). Marine Mammal Comm. Contr. No. MM 7AC029.
- Seber, G.A.F. 1973. The estimation of animal abundance. Hafner Publ. Co., Inc. New York. 506 pp.
- Sergeant, D.E. 1953. Whaling in Newfoundland and Labrador waters. Nor Hvalfangst-Tidende, Aarg. 42:687-695. (439-447 in some vols.)
- Sergeant, D.E. 1958. Dolphins in Newfoundland waters. Can. Field Nat. 72:156-159.
- Sergeant, D.E. 1961. Whales and Dolphins of the Canadian East Coast. Fish. Res. Bd. Canada., Circular No. 7. 17 pp.
- Sergeant, D.E. 1962. The biology of the pilot or pothead whale (Globicephala melaena (Trail)) in Newfoundland waters. Bull. Fish. Res. Bd. Can. 132. 84pp.
- Sergeant, D.E. 1963. Minke Whales, Balaenoptera acutorostrata Lacepede, of the western North Atlantic. J. Fish. Res. Bd. Can. 20:1489-1504.
- Sergeant, D.E. 1966. Populations of large whale species in the western North Atlantic with special references to the Fin Whale. Fish. Res. Bd. Can., circ. No. 9.
- Sergeant, D.E. 1968. Sightings of marine mammals. Int., Comm. North. Atl. Fish. Spec. Publ. No. 7:241-244.
- Sergeant, D.E. 1975. An additional food supply for Humpback (Megaptera novaeangliae) and Minke Whales (Balaenoptera acutorostrata). Int. Council. Expor. Sea. Mar. Mamm. Comm. CM 1975/No. 13:1-7.
- Sergeant, D.E. 1977. Stocks of Fin Whales Balaenoptera physalus L. in the North Atlantic Ocean. Rep. Int. Whal. Comm. 27:460-473.

- Sergeant, D.E., and H.D. Fisher, 1957. The Smaller Cetacea of Eastern Canadian Waters. J. Fish. Res. Bd. Can. 114:83-115.
- Sergeant, D.E., A.W. Mansfield, and B. Beck, 1970. Inshore records of Cetacea for eastern Canada, 1949-1968. J. Fish. Res. Bd. Can. 27:1903-1915.
- Sergeant, D.E., D.J. St. Aubin, and J.R. Geraci, 1980. Life History and northwest Atlantic status of the Atlantic White-Sided Dolphin, Lagenorhynchus acutus. Cetology 37:1-12.
- Setlow, L.W. 1973. Geological Investigation of the Project NOMES Dredging site. Publication No. 6937. Massachusetts Department of Natural Resources, Commonwealth of Massachusetts, Boston, MA.
- Sherk, J.A., J.M. O'Connor, and D.A. Neumann. 1975. Effects of suspended sediments on estuarine environments. In Estuarine Research. L.E. Cronin (ed.). pp. 541-558.
- Sherman, K., M. Grosslein, D. Mountain, D. Busch, J. O'Reilly, and R. Theroux. 1988. The continental shelf ecosystem off the Northeast Coast of the United States. In Ecosystems of the World Elsevier. Amsterdam.
- Sherman, K., M. Grosslein, D. Mountain, D. Busch, J. O'Reilly, and R. Thenouy 1988. The continental shelf ecosystem off the northeast coast of the United States. In (H. Poatma and JJ Zielstra PP 279.337 eds). Ecosystems of the World no. 27 Continental Shelf. Elsevier.
- Sherman, K.C., C. Jones, L. Sullivan, W. Smith, P. Berrein, and L. Ejustment, 1981. Congruent shifts in sand eel abundance in western and eastern north Atlantic exosystems. Nature 291:486-489.
- Sherman, K., W. Smith, W. Morse, M. Berman J. Green, and Ejsymont. 1984. Spawning strategies of fishes in relation to circulation, phytoplankton production, and pulses in zooplankton off the northeastern United States. Mar. Ecol. Prog. Ser. 18: 1-19.
- Shettig, P., S. Chenworth, B. Surgens. 1980. Fishes. In: "An Ecological Characterization of Coastal Maine. Biological Serv. Prog. FWS 10BS-80/29. Vol 3.
- Shoop, C.R. 1980. Sea turtles in the northeast. Maritmes, Nov. 1980 p. 9-11.
- Shoop, C.R., T.L. Doty, and N.E. Bray, 1981. Sea turtles in the region between Cape Hatteras and Nova Scotia in 1979. In A characterization of marine mammals and turtles in the Mid- and North Atlantic areas of the U.S. outer contiental shelf. CETAP Program, Univ. of Rhode Island, prepared for Bureau of Land Mgmt., U.S. Dept. of Interior, Washinton, D.C.

- Shoop, C.R., and C.A. Ruckdeschel, 1986. Atlantic Hawksbill Turtle (Eretmocely imbricata imbricata). In T. French (ed.). Endangered, threatened and special concern vertebrate species in Massachusetts. Mass. Div. of Fisheries and Wildlife, Nongame and Endangered Species Program, Boston, MA. 02202 (in press).
- Shoop, C.R., and C.A. Ruckdeschel, 1986. Atlantic Green Turtle (Chelonia mydas mydas). In T. French (ed.). Endangered, threatened and special concern vertebrate species in Massachusetts. Mass. Div. of Fisheries and Wildlife, Nongame and Endangered Species Program, Boston, MA. 02202 (in press).
- Sinderman, C.J. 1979. Pollution associated diseases and abnormalities of fish and shellfish. Fish. Bull. 76: 719-749.
- Sissenwine, M.P., B.E. Brown, J.E. Palmer, and R.J. Essig, 1982. Emprical examination of population interactions for the fishery resources off the Northeastern USA. In M.C. Mercer (ed.) Multispecies approaches to fisheries Managment advice. Can. Spec. Publ. Fish. Aquat. Sci. 59:82-94.
- Sissenwine, M.P., W.J. Overholtz, and S.H. Clark. 1983. In search of density dependence. Pp. 119-138 In B.R. Melteff (ed.) Proceedings of the workshop on Marine Mammal Fishery - Interactions of the east Bering Sea. Univ. of Alaska Sea Grant, Fairbanks, AK. 300 pp.
- Smigielski, A.S., T.A. Halavik, L.J. Buckley, S.M. Drew, G.C. Laurence. 1984. Spawning, embryo development and growth of the American sand lance Ammodytes americanus in the laboratory. Mar. Ecol, Prog. Ser. 14: 287-292.
- Smith, F.G. Walton, 1974. Handbook of Marine Science. Volume I. CRC Press.
- Smith, G.J.D., and D.E. Gaskin, 1974. The diet of harbor porpoises (Phocoena phocoena [L.]) in coastal waters of eastern Canada, with special reference to the Bay of Fundy. Can. J. Zool. 52:777-782.
- Smith, J., J.Y. Hauser and J. Bagg, 1985. Polycyclic Aromatic Hydrocarbons in sediments of the Great Barrier Reef region, Australia. Mar. Poll. Bull. 16: 110-114.
- Smith, W.D., L. Sullivan, and P. Berrien, 1978. Fluctuations in production of sand lance larvae in coastal waters off the northeastern United States, 1974 to 1977. ICES C.M. 1978/L:30, unpubl. Doc., 8 pp.
- Smith, W.O., Jr. 1982. The relative importance of chlorophyll, dissolved and particulate material and seawater to the vertical extinction of light. Est. Coast. Shelf Sci. 15: 459-465.

- Sonstegard, R.A. and J.F. Leatherland. 1984 . Comparative epidemiology: the uses of fishes in assessing carcinogenic contaminants. pp 224-231 In: (V.W. Cairns et al. eds). Advances in Environmental Science and Technology. Contaminant effects on fisheries. Wiley.
- Sowl, L.W. and J.C. Bartonek, 1974. Seabirds - Alaska's most neglected resource. Trans. N. Am. Wildl. and Nat. Res. Conf. 39:117-126.
- Stern, E.M. and W.B. Stickle. 1978. Effects of Turbidity and Suspended Material in Aquatic Environments. Tech. Rep. D-78-21. U.S. Army Waterways Exp. Stat. Vicksburg. Miss.
- Stick, D. 1958. The outer banks of North Carolina 1584-1958. U. No. Caro. Press, Chapel Hill, NC.
- Stoddard, A., R. Wells, and K. Devonald, 1985. Development and application of a deepwater ocean waste disposal model for dredged material: Yabucoa Harbor, Puerto Rico. MTS Jour. 19:26-39.
- Stone, G., S. Katona, and J. Beard, 1983. Whales in the Gulf of Maine 1978-1981. Report of the Gulf of Maine Whale Sighting Network.
- Sub-Sea Surveyors, Inc. 1973. Report of underwater television survey of Massachusetts Bay "Massachusetts Bay - Explosives" for U.S. Army Corps of Engineers, Waltham, MA. Kittery, ME.
- Sullivan, B.K. and D. Hancock. 1977. Zooplankton and dredging: research perspectives from a critical review. Water Res. Bull. 13: 461-467.
- Sutcliffe, W.H., and P.F. Brodie, 1977. Whale distributions on Nova Scotia Waters Fisheries and Marine Service Technical Report No. 722. Fisheries and Marine Service, Bedford Institute of Oceanography, Dartmouth, Nova Scotia. 83 pp.
- Sutcliffe, W.H. Jr., R.H. Loucks, and K.F. Drinkwater, 1976. Coastal circulation and physical oceanography of the Scotian Shelf and the Gulf of Maine. J. of the Fish. Res. Board of Canada. 33:98-115.
- Sweeney, R.A. 1978. Aquatic Disposal Field Investigations Ashtabula River Disposal Site, Ohio. Evaluative Summary. Tech. Rep. D-77-42. U.S. Army Waterways Exp. Stat. Vicksburg. Miss.
- Swenson, W.A. and M.A. Matson. 1976. Influence of turbidity on survival, growth, and distribution of larval lake herring (Coregonus artedii). Trans. Amer. Fish. Soc. 4: 541-545.
- Symada, T.J. 1983. The phytoplankton of estuaries. In Estuaries of the World 26. Estuaries and Enclosed Seas. B.H. Ketchum (ed.). Elsevier. pp. 65-102.

- Tavolaro, J.F. 1982. Sediment budget study for clamshell dredging and disposal activities. Tech. Manuscript. U.S. Army Corps of Engineers, New York District.
- Testaverde, S.A., and J.G. Mead, 1980. Southern distribution of the Atlantic whitesided dolphin, Lagenorgynchus acutus, in the western North Atlantic. Fish. Bull. 78:167-169.
- Thurston, R.U., R.C. Russo, C.M. Fetterolf, Jr., T.A. Edsall and Y. M. Barber, Jr. (Eds.) 1979. A review of the EPA Red Book: Quality criteria for water. Water Quality Section, American Fisheries Society, Bethesda, MD. 313 p.
- Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. Zoologica 19:3-17.
- TRIGOM. 1974. A Socio-Economic and Environmental Inventory of the North Atlantic Region (Vol 1, Book 3). South Portland, Maine.
- True, F.W. 1904. The Whalebone Whales of the western North Atlantic compared with those occurring in European waters. Smithson. Contrib. Knowl. 33:1-332.
- Truitt, C.L. 1986. Fate of Dredged Material During Open-water Disposal. Envir. Effects Dredg. Tech. Notes. EEDP-01-2. U.S. Army Waterways Exp. Stat. Vicksburg. Miss.
- U.S. Department of Commerce, NOAA, Environmental Data Service, National Climatic Center, 1979. Climate of Massachusetts. Climatography of the United States, Asheville, NC.
- U.S. Department of Commerce, NOAA, National Ocean Survey, 1980. Outer Continental Shelf Resource Management Map, Boston, NOS NK 19-4 (OCS), Rockville, MD.
- Van Bree, P.J., and H. Nigssen, 1964. On three specimens of Lagenorhynchus albirostris gray, 1846 (Mammalia, Cetacea). Beaufortia 11:85-93.
- Viarengo, A. 1985. Biochemical effects of trace metals. Mar. Poll. Bull. 16:153-158
- Wakeman, T., R. Peddicord, and J. Sustar. 1975. Effects of suspended solids associated with dredging operations on estuarine organisms. IEEE Ocean '75. pp. 431-436.
- Watkins, W.A., K.E. Moore, J. Sigurjonsson, D. Wartzok, and G.N. di Sciara, 1981. Finback whale, Balaenoptera physalus tracked by radio from Icelandic to Greenlandic waters. ICES-CM-1981/N:16.



- Watkins, W.A., and W.E. Schevill, 1976. Right whale feeding and baleen rattle. *J. Mamm.* 57:58-66.
- Watkins, W.A. and W.E. Schevill, 1979. Aerial observation of feeding behavior in four baleen whales: Eubalaena glacialis, Balaenoptera borealis, Magaptera novaeangliae, and Balaenoptera physalus. *J. Mamm.* 60:155-63.
- Watkins, W.A., and W.E. Schevill, 1982. Observations of right whales, Eubalaena glacialis, in Cape Cod waters. *Fishery Bulletin* 80:875-880.
- Watson, L. 1981. Sea guide to whales of the world. E.P. Dutton, New York. 302 pp.
- Wedemeyer, G.A., D.J. McLeay, and C.P. Goodyear. 1984. Assessing the tolerance of fish and fish populations to environmental stress: the problems and methods of monitoring. In *Contaminant Effects on Fisheries*. V.W. Cairns et al. (eds.). *Advances in Environ. Sci. Tech.* Wiley. pp. 163-195.
- Weinrich, M.T. 1982. Biology of the humpback whale (Megaptera novaeangliae): Northern Stellwagen Bank, Summer, 1981. *Cetacean Researc Unit Special Report No. 1*.
- Weinrich, M.T. 1985. Long term association patterns of humpback whales in the southern Gulf of Maine. Pp. 18-27 In *Humpback whales of the southern Gulf of Maine: recent findings on habitat use, social behavior and feeding patterns*. Cet. Res. Unit, Glouc. Fish. Mus., Gloucester, MA.
- Weinrich, M.T., C.R. Belt, H.J. Iken, and M.R. Schilling. 1985. Individual variation in feeding patterns of humpback whales (Megaptera novaeangliae) in New England. Pp. 28-41 In *Humpback whales of the southern Gulf of Maine: recent findings on habitat use, social behavior and feeding patterns*. Cet. Res. Unit, Glouc. Fish. Mus., Gloucester, MA.
- Weiss, H.B. 1974. Whaling in New Jersey. N.J. Agricul. Soc., Trenton, NJ.
- Whitehead, H. 1982. Populations of humpback whales in the northwest Atlantic. *Rept. Int. Whal. Comm.* 32:345-353.
- Whitehead, H., K. Chu, J. Perkins, P. Bryant, and G. Nichols, Jr. 1983. Population size, stock identity and distribution of the humpback whales off West Greenland - summer 1981. *Rep. Int. Whal. Comm.* 33:497-502.

- Whitehead, H., and C. Glass. 1985a. The significance of the southeast Shoal of the Grand Bank to humpback whales and other cetacean species. *Can. J. Zool.* 63:2617-2625.
- Whitehead, H., and C. Glass. 1985b. Orcas (killer whales) attack humpback whales. *J. Mamm.* 66:183-185.
- Whitehead, H., P. Harcourt, K. Ingham, and H. Clark. 1980. The migration of humpback whales, past the Bay de Verde Peninsula, Newfoundland, during June and July, 1978. *Can. J. Zool.* 58:687-692.
- Whitehead, H., and M.J. Moore. 1982. Distribution and movements of West Indian humpback whales in winter. *Can. J. Zool.* 60:2203-2211.
- Whitehead, H., R. Silver, and P. Harcourt. 1982. The migration of humpback whales along the northeast coast of Newfoundland. *Can. J. Zool.* 60:2173-2179.
- Wildish, D.J. and J. Power. 1985. Avoidance of suspended sediments by smelt as determined by a new "single fish" behavioral bioassay. *Bull. Environ. Contam. Tox.* 34: 770-774.
- Willetts, C.F. 1972. Final Report of Massachusetts Coastal Mineral Inventory Survey. Massachusetts Department of Natural Resources, Commonwealth of Massachusetts, Boston, MA.
- Williams, A. B. 1984. Shrimps, Lobsters, and Crabs of the Atlantic Coast of the Eastern United States, Maine to Florida. *Smith. Inst. Press.* Washington D.C.
- Windsor, J.G. Jr. and R.A. Hites, 1979. Polycyclic Aromatic Hydrocarbons in Gulf of Maine sediments and Nova Scotia soils. *Geo. ef. Cosmo. Acta.* 43: 27-33.
- Winn, H.E., R.K. Edel, and A.G. Taruski. 1975. Population estimates of the humpback whale (Magaptea novaeangliae) in the West Indies by visual and acoustic techniques. *J. Fish. Res. Bd. Can.* 32:499-506.
- Winn, H.E., D.R. Goodale, M.A.M. Hyman, R.D. Kenney, C.A. Price, and G. P. Scott. 1981. Right whale sightings and the right whale minimum count. In A characterization of marine mammals and turtles in the Mid- and North-Atlantic areas of the U.S. outer Continental Shelf. Ann. Rept. 1979, CETAP Program, Univ. of Rhode Island, prepared for Bureau of Lnd Mgmt., U.S. Dept. of Interior, Washington D.C.
- Winn, H.E., P.W. Sorenson, and C.A. Price. 1984. The distributional biology of the right whale, Eubalaena glacialis, from Cape Hatteras to Nova Scotia. Draft Final Rept., Contract No. 14-12-0001-30091. Min. Mgmt. Serv., U.S. Dept. of the Interior, Washington, D.C.

- Wolf, D.A. et. al. 1982. Effects of toxic substances on communities and ecosystems. In Ecological Stress and the New York Bight. Science and Management. G.F. Myer (ed.). Est. res. Fed. South. Carolina. pp. 68-86.
- Wright, T.D. 1978. Aquatic Dredged Material Disposal Impacts. Tech. Rep. DS-78-1. U.S. Army Waterways Exp. Stat. Vicksburg, Miss.
- Yingst, J.Y. and D.C. Rhoads. 1978. Seafloor stability in central Long Island Sound. Pt. II. Biological interactions and their potential importance for seafloor erodibility, in Estuarine Interactions, M.L. Wiley, ed., Academic Press, N.Y., 603 pp.
- Ziskowski, J.J., L. Despres-Patanjo, R.A. Murchelano, A.B. Howe, D. Raiph, and S. Atran. 1987. Disease of commercially valuable fish stocks in the northwest Atlantic. Mar. Pol. Bull. 18: 496-504.

APPENDIX I

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Table I-1

Results Of The Bivariate Analysis Of 3-HLP Current Meter Data Collected  
At FADS At A Depth Of 10m For The Period Of Sep 20 - Oct 18, 1985

| FREQUENCY DISTRIBUTION  |     |     |      | STATION# FAD21                  |    | SPANNING 9/20/85 TO 10/18/85 |    | 674 DATA POINTS    |      |       |       |                    |       |
|---|-----|-----|------|---------------------------------|----|------------------------------|----|--------------------|------|-------|-------|--------------------|-------|
| 1.00 HRS/INT DATA   |     |     |      | 300L                            |    |                              |    |                    |      |       |       |                    |       |
| DIRECTION DEGREES   |     |     |      |                                 |    |                              |    | PERCENT            |      |       |       |                    |       |
|   |     |     |      |                                 |    |                              |    | MEAN MID SPEED     |      |       |       |                    |       |
|   |     |     |      |                                 |    |                              |    | MAX SPEED          |      |       |       |                    |       |
|   |     |     |      |                                 |    |                              |    | STD. DEV.          |      |       |       |                    |       |
| 0-30  | .4  | 4.0 | 3.0  | 1.0                             | .1 | .0                           | .1 | .3                 | 11.9 | 23.34 | 3.10  | 77.44              | 16.26 |
| 30-60   | .9  | 2.4 | 10.4 | 5.3                             | .7 | .1                           | .1 | .0                 | 20.2 | 27.18 | 3.36  | 65.87              | 8.50  |
| 60-90   | 1.3 | 2.0 | 8.3  | 4.3                             | .1 | .0                           | .0 | .0                 | 17.1 | 24.40 | 3.62  | 49.30              | 9.28  |
| 90-120  | .3  | 1.2 | 3.3  | .6                              | .3 | .0                           | .0 | .0                 | 3.6  | 23.72 | 2.46  | 48.25              | 9.26  |
| 120-150   | .0  | 1.6 | 2.1  | .6                              | .0 | .1                           | .0 | .0                 | 4.3  | 23.06 | 11.00 | 58.98              | 10.50 |
| 150-180   | .1  | 2.1 | 1.2  | .6                              | .1 | .3                           | .1 | .0                 | 4.6  | 25.00 | 7.63  | 60.53              | 10.16 |
| 180-210   | .7  | 1.9 | 1.6  | .6                              | .6 | .3                           | .0 | .0                 | 5.8  | 22.74 | .43   | 53.82              | 15.22 |
| 210-240   | 1.2 | 2.2 | 1.2  | 1.2                             | .1 | .1                           | .0 | .0                 | 6.1  | 20.20 | 3.50  | 53.23              | 12.93 |
| 240-270   | 1.8 | 2.4 | .6   | .6                              | .1 | .0                           | .0 | .0                 | 5.3  | 15.72 | 2.11  | 43.50              | 10.78 |
| 270-300   | 2.1 | 3.0 | 2.7  | .1                              | .0 | .0                           | .0 | .0                 | 7.9  | 16.42 | 1.60  | 30.82              | 7.63  |
| 300-330   | .9  | 3.0 | 1.3  | .3                              | .0 | .0                           | .0 | .0                 | 5.3  | 16.87 | 3.95  | 32.84              | 7.81  |
| 330-360   | 1.2 | 3.3 | 1.0  | .0                              | .0 | .0                           | .0 | .0                 | 5.3  | 15.47 | 2.10  | 20.29              | 6.30  |
| 100.00  |     |     |      |                                 |    |                              |    |                    |      |       |       |                    |       |
| SUMMARY STATISTICS  |     |     |      |                                 |    |                              |    |                    |      |       |       |                    |       |
| MEAN SPEED = 22.41 CM/S   |     |     |      | MAXIMUM = 77.44 CM/S            |    |                              |    | MINIMUM = .43 CM/S |      |       |       | RANGE = 77.01 CM/S |       |
| STANDARD DEVIATION = 10.60 CM/S   |     |     |      |                                 |    |                              |    | SKEWNESS = .09     |      |       |       |                    |       |
| IN A COORDINATE SYSTEM WHERE Y AXIS IS POSITIONED .60 DEGREES CLOCKWISE FROM TRUE NORTH |     |     |      |                                 |    |                              |    |                    |      |       |       |                    |       |
| MEAN Y COMPONENT = 6.06 CM/S  |     |     |      | STANDARD DEVIATION = 16.46 CM/S |    |                              |    | SKEWNESS = -.24    |      |       |       |                    |       |
| MEAN X COMPONENT = 6.00 CM/S  |     |     |      | STANDARD DEVIATION = 16.32 CM/S |    |                              |    | SKEWNESS = -.43    |      |       |       |                    |       |

Table I-2

Results Of The Bivariate Analysis Of 3-HLP Current Meter Data  
Collected At FADS At A Depth Of 82m (4m from the bottom) For The  
Period Of September 20 - October 18, 1985

| FREQUENCY DISTRIBUTION  |      |      |                                |      |      |                    |         |               |                   |              |           |
|---|------|------|--------------------------------|------|------|--------------------|---------|---------------|-------------------|--------------|-----------|
| 1.00 HOURS DATA   |      |      |                                |      |      |                    |         |               |                   |              |           |
| STATION FADS 300LP  |      |      |                                |      |      |                    |         |               |                   |              |           |
| SPANNING 9/20/85 TO 10/18/85  |      |      |                                |      |      |                    |         |               |                   |              |           |
| 675 DATA POINTS   |      |      |                                |      |      |                    |         |               |                   |              |           |
| DIRECTION<br>DEGREES  |      |      |                                |      |      |                    | PERCENT | MEAN<br>SPEED | MIN<br>SPEED      | MAX<br>SPEED | STD. DEV. |
| 0-30  | 2.0  | 1.2  | .3                             | .9   | .6   | .0                 | 3.8     | 6.59          | .43               | 17.00        | 5.95      |
| 30-60   | 2.5  | .7   | .1                             | 1.6  | 1.0  | .1                 | 6.2     | 8.61          | .21               | 20.35        | 7.23      |
| 60-90   | 4.1  | 1.2  | .3                             | .7   | 1.9  | .1                 | 8.4     | 7.43          | .11               | 21.90        | 7.40      |
| 90-120  | 5.0  | 3.4  | 2.1                            | 1.5  | 1.9  | .9                 | 15.6    | 8.13          | .10               | 21.31        | 6.97      |
| 120-150   | 3.9  | .6   | .7                             | .9   | .9   | .0                 | 7.9     | 8.35          | .17               | 23.06        | 7.09      |
| 150-180   | 2.4  | .3   | .1                             | .3   | .1   | .1                 | 3.4     | 5.63          | .30               | 23.59        | 5.67      |
| 180-210   | 2.0  | .4   | .1                             | .0   | .1   | .0                 | 3.6     | 3.09          | .35               | 16.36        | 6.06      |
| 210-240   | 4.4  | .6   | .1                             | .3   | .4   | .0                 | 5.9     | 6.37          | .02               | 19.65        | 6.97      |
| 240-270   | 5.2  | 2.2  | .0                             | .6   | 1.3  | .4                 | 9.9     | 6.06          | .23               | 24.59        | 7.13      |
| 270-300   | 7.4  | 6.3  | 1.0                            | 2.2  | 3.6  | 1.8                | 20.3    | 9.02          | .63               | 23.59        | 7.34      |
| 300-330   | 4.0  | .6   | .4                             | .6   | 1.5  | .1                 | 7.3     | 7.30          | .17               | 20.00        | 7.06      |
| 330-360   | 3.7  | .4   | .0                             | .9   | .7   | .0                 | 5.0     | 5.65          | .23               | 18.57        | 6.00      |
| SPEED   | 0    | 4    | 8                              | 12   | 16   | 20                 |         |               |                   |              |           |
| CM/S  | 1    | 1    | 1                              | 1    | 1    | 1                  |         |               |                   |              |           |
|   | 4    | 8    | 12                             | 16   | 20   | 24                 |         |               |                   |              |           |
| PERCENT   | 49.0 | 16.0 | 5.5                            | 10.5 | 14.2 | 4.6                | 100.00  |               |                   |              |           |
| MEAN DIR  | 193  | 107  | 140                            | 171  | 194  | 199                |         |               |                   |              |           |
| STD DEV   | 102  | 99   | 90                             | 115  | 106  | 91                 |         |               |                   |              |           |
| SUMMARY STATISTICS  |      |      |                                |      |      |                    |         |               |                   |              |           |
| MEAN SPEED = 7.40 CM/S  |      |      | MAXIMUM = 24.59 CM/S           |      |      | MINIMUM = .02 CM/S |         |               | BIAS = 24.37 CM/S |              |           |
| STANDARD DEVIATION = 6.00 CM/S  |      |      |                                |      |      | SKEWNESS = .70     |         |               |                   |              |           |
| IN A COORDINATE SYSTEM WHERE Y AXIS IS POSITIONED .00 DEGREES CLOCKWISE FROM TRUE NORTH |      |      |                                |      |      |                    |         |               |                   |              |           |
| MEAN X COMPONENT = -.33 CM/S  |      |      | STANDARD DEVIATION = 8.64 CM/S |      |      | MEANNESS = -.16    |         |               | SKEWNESS = -.21   |              |           |
| MEAN Y COMPONENT = .55 CM/S   |      |      | STANDARD DEVIATION = 5.10 CM/S |      |      | SKEWNESS = .21     |         |               |                   |              |           |



Table I-3

Results of the Bivariate Analysis of Near-bottom (82m) 3-HLP  
Current Speed and Direction at FADS (15 Feb. - 2 Apr., 1986)

| FREQUENCY DISTRIBUTION     |       |       |        |         |         |         |         |         |         |         |         |
|----------------------------|-------|-------|--------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1.00 HOURS DATA            |       |       |        |         |         |         |         |         |         |         |         |
| STATION: FADS1             |       |       |        |         |         |         |         |         |         |         |         |
| SPANNING 2/15/86 TO 4/2/86 |       |       |        |         |         |         |         |         |         |         |         |
| 1111 DATA POINTS           |       |       |        |         |         |         |         |         |         |         |         |
| DIRECTION                  |       |       |        |         |         |         |         |         |         |         |         |
| DEGREES                    |       |       |        |         |         |         |         |         |         |         |         |
| 0-30                       | 30-60 | 60-90 | 90-120 | 120-150 | 150-180 | 180-210 | 210-240 | 240-270 | 270-300 | 300-330 | 330-360 |
| 4.0                        | 5.8   | 7.5   | 14.0   | 10.4    | 4.1     | 6.2     | 6.9     | 6.1     | 7.6     | 3.9     | 3.2     |
| .4                         | .9    | .8    | 3.0    | 3.3     | 1.5     | 1.2     | 1.2     | .3      | 1.2     | .9      | .5      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .2      | .6      | .1      | .7      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    | .0     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
| .0                         | .0    | .0    |        |         |         |         |         |         |         |         |         |

### Results of the Bivariate Analysis of Near-surface (8 m) 3-HLP Current Speed and Direction at FADS (12 Sept. - 19 Oct., 1987)

[illegible]

|   |                                       |
|---|---------------------------------------|
| IN A COORDINATE SYSTEM WHERE Y AXIS IS POSITIONED | .00 DEGREES CLOCKWISE FROM TRUE NORTH |
| MEAN Z COMPONENT =                                | -2.60 CM/S                            |
| STANDARD DEVIATION =                              | 9.54 CM/S                             |
| MEAN Y COMPONENT =                                | -0.11 CM/S                            |
| STANDARD DEVIATION =                              | 15.99 CM/S                            |
| SKEMNESS =  | -73                                   |
| SKEMNESS =  | -72                                   |

Table I-5

Results of the Bivariate Analysis of Mid-depth (25 m) 3-HLP  
Current Speed and Direction at FADS (12 Sept. - 19 Oct., 1987)

| FREQUENCY DISTRIBUTION<br>1.00 HOURLY DATA  |  |            |       |       |        |         |         |         |         |         |         |         |         |
|---|--|------------|-------|-------|--------|---------|---------|---------|---------|---------|---------|---------|---------|
| 847 DATA POINTS   |  |            |       |       |        |         |         |         |         |         |         |         |         |
| DIRECTION<br>DEGREES  |  | PERCENT    |       |       |        |         |         |         |         |         |         |         |         |
|   |  | 0-30       | 30-60 | 60-90 | 90-120 | 120-150 | 150-180 | 180-210 | 210-240 | 240-270 | 270-300 | 300-330 | 330-360 |
|   |  | .7         | 3.9   | 3.3   | 1.9    | 1.2     | .6      | .0      | .0      | .0      | .0      | .0      | .0      |
|   |  | .7         | 1.3   | 2.7   | 1.2    | .6      | .7      | .1      | .0      | .0      | .0      | .0      | .0      |
|   |  | .7         | .7    | 1.9   | 2.4    | .3      | .1      | .0      | .0      | .0      | .0      | .0      | .0      |
|   |  | .1         | 1.2   | 1.7   | 2.1    | .4      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
|   |  | .4         | 1.9   | 2.1   | .9     | .0      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
|   |  | .4         | 1.7   | .9    | .6     | .6      | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
|   |  | .4         | 2.0   | .0    | .2     | .0      | .6      | .0      | .0      | .0      | .0      | .0      | .0      |
|   |  | 1.3        | 2.0   | 2.2   | 2.0    | .0      | .4      | .6      | .3      | .0      | .0      | .0      | .0      |
|   |  | .2         | 2.0   | 2.5   | 2.4    | .9      | .6      | .4      | .4      | .1      | .7      | .6      | .1      |
|   |  | .3         | 2.0   | 4.3   | 2.0    | .0      | .3      | .3      | .0      | .0      | .0      | .0      | .0      |
|   |  | .4         | 1.9   | 4.0   | 2.2    | 2.2     | .0      | .0      | .0      | .0      | .0      | .0      | .0      |
|   |  | .0         | 2.7   | 4.3   | 3.0    | 1.1     | .2      | .0      | .0      | .0      | .0      | .0      | .0      |
| SPEED   |  | 0          | 5     | 10    | 15     | 20      | 25      | 30      | 35      | 40      | 45      | 50      | 55      |
| CM/S  |  | 1          | 1     | 1     | 1      | 1       | 1       | 1       | 1       | 1       | 1       | 1       | 1       |
|   |  | 5          | 10    | 15    | 20     | 25      | 30      | 3       | 40      | 45      | 50      | 55      | 60      |
| PERCENT   |  | 7.0        | 23.3  | 31.2  | 20.9   | 9.9     | 3.7     | 1.3     | .0      | .1      | .7      | .4      | .1      |
| MEAN DIR  |  | 105        | 103   | 200   | 196    | 215     | 166     | 235     | 241     | 263     | 252     | 259     | 253     |
| STD DEV   |  | 109        | 113   | 117   | 114    | 108     | 115     | 69      | 30      | 0       | 40      | 52      | 01      |
|   |  | 100.00     |       |       |        |         |         |         |         |         |         |         |         |
| SUMMARY STATISTICS  |  |            |       |       |        |         |         |         |         |         |         |         |         |
| MEAN SPEED  |  | 14.22 CM/S |       |       |        |         |         |         |         |         |         |         |         |
| STANDARD DEVIATION  |  | 8.02 CM/S  |       |       |        |         |         |         |         |         |         |         |         |
| MAXIMUM   |  | 56.39 CM/S |       |       |        |         |         |         |         |         |         |         |         |
| MINIMUM   |  | -.25 CM/S  |       |       |        |         |         |         |         |         |         |         |         |
| SKEWNESS  |  | 1.64       |       |       |        |         |         |         |         |         |         |         |         |
| RANGE   |  | 56.64 CM/S |       |       |        |         |         |         |         |         |         |         |         |
| IN A COORDINATE SYSTEM WHOSE Y AXIS IS POSITIONED .00 DEGREES CLOCKWISE FROM TRUE NORTH |  |            |       |       |        |         |         |         |         |         |         |         |         |
| MEAN X COMPONENT  |  | -1.74 CM/S |       |       |        |         |         |         |         |         |         |         |         |
| STANDARD DEVIATION  |  | 12.09 CM/S |       |       |        |         |         |         |         |         |         |         |         |
| MEAN Y COMPONENT  |  | 2.10 CM/S  |       |       |        |         |         |         |         |         |         |         |         |
| STANDARD DEVIATION  |  | 10.29 CM/S |       |       |        |         |         |         |         |         |         |         |         |
| SKEWNESS  |  | -.75       |       |       |        |         |         |         |         |         |         |         |         |
| SKEWNESS  |  | -.20       |       |       |        |         |         |         |         |         |         |         |         |

Table I-6

Results of the Bivariate Analysis of Mid-depth (55 m) 3-HLP  
Current Speed and Direction at FADS (12 Sept. - 19 Oct., 1987)

| FREQUENCY DISTRIBUTION<br>1.00 HOURLY DATA  |            |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
|---|------------|-----|------|------|------|------|------|-----|-----|-----|---------|---------------|--------------|-----------|--------|
| DIRECTION<br>DEGREES  |            |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| 007 DATA POINTS   |            |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
|   |            |     |      |      |      |      |      |     |     |     | PERCENT | MEAN<br>SPEED | MIN<br>SPEED | STD. DEV. |        |
|   |            |     |      |      |      |      |      |     |     |     |         |               | MAX<br>SPEED |           |        |
|   |            |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| 0-30  | -1         | .7  | 1.2  | 1.4  | 1.7  | 1.2  | .4   | .0  | .0  | .0  | 6.0     | 7.72          | 1.38         | 13.36     | 3.32   |
| 30-60   | -2         | .4  | .4   | 1.0  | 1.5  | 1.4  | .4   | .1  | .0  | .0  | 6.4     | 8.30          | 1.49         | 14.32     | 2.77   |
| 60-90   | 0          | .2  | 1.7  | 1.5  | 1.3  | .4   | .2   | .3  | .1  | .0  | 5.7     | 7.62          | 2.48         | 16.56     | 3.41   |
| 90-120  | -1         | .7  | 2.2  | 1.8  | 2.2  | .4   | .7   | .1  | .6  | .0  | 6.9     | 8.04          | 1.39         | 17.22     | 3.49   |
| 120-150   | -6         | .5  | .9   | 1.2  | 1.9  | 1.5  | .8   | .5  | .2  | .0  | 7.4     | 9.37          | 2.21         | 17.08     | 3.18   |
| 150-180   | -2         | .4  | 1.3  | 1.2  | 2.1  | .8   | .8   | .2  | .1  | .0  | 7.2     | 8.08          | 1.39         | 16.72     | 3.26   |
| 180-210   | -2         | .1  | .8   | 1.0  | 1.0  | 1.3  | .7   | .5  | .0  | .0  | 7.2     | 8.82          | 1.05         | 15.44     | 3.25   |
| 210-240   | -2         | .5  | 1.1  | 2.2  | .8   | .6   | .8   | .0  | .0  | .0  | 6.3     | 7.64          | .79          | 13.16     | 2.96   |
| 240-270   | -2         | .5  | 1.1  | 1.5  | 1.3  | .2   | .2   | .5  | .0  | .0  | 5.4     | 7.49          | .69          | 16.86     | 3.43   |
| 270-300   | -2         | .7  | 1.2  | 2.2  | 4.0  | 3.0  | 1.4  | .7  | .0  | .1  | 13.6    | 9.18          | 1.79         | 18.10     | 3.04   |
| 300-330   | -1         | .9  | 1.1  | 1.8  | 3.2  | 2.4  | 3.3  | 1.7 | .7  | .1  | 15.3    | 10.49         | 1.37         | 21.18     | 3.68   |
| 330-360   | -6         | .4  | 1.1  | 2.2  | 2.0  | 2.6  | 1.2  | .1  | .0  | .0  | 9.7     | 9.17          | 2.29         | 22.66     | 3.07   |
| SPEED   | 0          | 2   | 4    | 6    | 8    | 10   | 12   | 14  | 16  | 18  | 20      | 22            |              |           |        |
| CM/S  | 2          | 4   | 6    | 8    | 10   | 12   | 14   | 16  | 18  | 20  | 22      | 24            |              |           |        |
| PERCENT   | 1.0        | 5.9 | 14.2 | 20.7 | 23.8 | 19.7 | 11.2 | 4.4 | 1.9 | .2  | .1      | .1            |              |           |        |
| MEAN DIR  | 180        | 168 | 172  | 195  | 199  | 217  | 232  | 239 | 197 | 302 | 324     | 331           |              |           |        |
| STD DEV   | 88         | 111 | 104  | 104  | 105  | 112  | 100  | 92  | 105 | 48  | 0       | 01            |              |           | 100.00 |
| SUMMARY STATISTICS  |            |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| MEAN SPEED  | 8.78 CM/S  |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| STANDARD DEVIATION  | 3.43 CM/S  |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| MINIMUM   | 22.66 CM/S |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| MAXIMUM   | .49 CM/S   |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| SKENNESS  | .29        |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| RANGE   | 21.97 CM/S |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| IN A COORDINATE SYSTEM WHOSE Y AXIS IS POSITIONED .00 DEGREES CLOCKWISE FROM TRUE NORTH |            |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| MEAN X COMPONENT  | -1.26 CM/S |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| STANDARD DEVIATION  | 4.58 CM/S  |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| MEAN Y COMPONENT  | .97 CM/S   |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| STANDARD DEVIATION  | 4.56 CM/S  |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| SKENNESS  | .14        |     |      |      |      |      |      |     |     |     |         |               |              |           |        |
| SKENNESS  | -.20       |     |      |      |      |      |      |     |     |     |         |               |              |           |        |

Table I-7

Results of the Bivariate Analysis of Near-bottom (84 m) 3-HLP  
Current Speed and Direction at FADS (12 Sept. - 19 Oct., 1987)

| FREQUENCY DISTRIBUTION<br>1.00 HOURLY DATA |       |       |       |        |         |         |         |         |         |         |         |         |
|--|-------|-------|-------|--------|---------|---------|---------|---------|---------|---------|---------|---------|
| 847 DATA PPT-18                            |       |       |       |        |         |         |         |         |         |         |         |         |
| DIRECTION<br>DEGREES                       | 0-30  | 30-60 | 60-90 | 90-120 | 120-150 | 150-180 | 180-210 | 210-240 | 240-270 | 270-300 | 300-330 | 330-360 |
| PERCENT                                    | 4.0   | 4.4   | 4.0   | 4.0    | 4.0     | 4.0     | 4.0     | 4.0     | 4.0     | 4.0     | 4.0     | 4.0     |
| MEAN SPEED                                 | 1.47  | 1.47  | 1.47  | 1.47   | 1.47    | 1.47    | 1.47    | 1.47    | 1.47    | 1.47    | 1.47    | 1.47    |
| MIN SPEED                                  | .81   | .81   | .81   | .81    | .81     | .81     | .81     | .81     | .81     | .81     | .81     | .81     |
| MAX SPEED                                  | 3.40  | 3.40  | 3.40  | 3.40   | 3.40    | 3.40    | 3.40    | 3.40    | 3.40    | 3.40    | 3.40    | 3.40    |
| STD. DEV.                                  | .72   | .72   | .72   | .72    | .72     | .72     | .72     | .72     | .72     | .72     | .72     | .72     |
| PERCENT                                    | 7.4   | 7.4   | 7.4   | 7.4    | 7.4     | 7.4     | 7.4     | 7.4     | 7.4     | 7.4     | 7.4     | 7.4     |
| MEAN SPEED                                 | 2.14  | 2.14  | 2.14  | 2.14   | 2.14    | 2.14    | 2.14    | 2.14    | 2.14    | 2.14    | 2.14    | 2.14    |
| MIN SPEED                                  | .34   | .34   | .34   | .34    | .34     | .34     | .34     | .34     | .34     | .34     | .34     | .34     |
| MAX SPEED                                  | 14.02 | 14.02 | 14.02 | 14.02  | 14.02   | 14.02   | 14.02   | 14.02   | 14.02   | 14.02   | 14.02   | 14.02   |
| STD. DEV.                                  | 3.19  | 3.19  | 3.19  | 3.19   | 3.19    | 3.19    | 3.19    | 3.19    | 3.19    | 3.19    | 3.19    | 3.19    |
| PERCENT                                    | 10.6  | 10.6  | 10.6  | 10.6   | 10.6    | 10.6    | 10.6    | 10.6    | 10.6    | 10.6    | 10.6    | 10.6    |
| MEAN SPEED                                 | 2.30  | 2.30  | 2.30  | 2.30   | 2.30    | 2.30    | 2.30    | 2.30    | 2.30    | 2.30    | 2.30    | 2.30    |
| MIN SPEED                                  | .33   | .33   | .33   | .33    | .33     | .33     | .33     | .33     | .33     | .33     | .33     | .33     |
| MAX SPEED                                  | 9.09  | 9.09  | 9.09  | 9.09   | 9.09    | 9.09    | 9.09    | 9.09    | 9.09    | 9.09    | 9.09    | 9.09    |
| STD. DEV.                                  | 1.35  | 1.35  | 1.35  | 1.35   | 1.35    | 1.35    | 1.35    | 1.35    | 1.35    | 1.35    | 1.35    | 1.35    |
| PERCENT                                    | 6.4   | 6.4   | 6.4   | 6.4    | 6.4     | 6.4     | 6.4     | 6.4     | 6.4     | 6.4     | 6.4     | 6.4     |
| MEAN SPEED                                 | 1.86  | 1.86  | 1.86  | 1.86   | 1.86    | 1.86    | 1.86    | 1.86    | 1.86    | 1.86    | 1.86    | 1.86    |
| MIN SPEED                                  | .81   | .81   | .81   | .81    | .81     | .81     | .81     | .81     | .81     | .81     | .81     | .81     |
| MAX SPEED                                  | 5.71  | 5.71  | 5.71  | 5.71   | 5.71    | 5.71    | 5.71    | 5.71    | 5.71    | 5.71    | 5.71    | 5.71    |
| STD. DEV.                                  | .27   | .27   | .27   | .27    | .27     | .27     | .27     | .27     | .27     | .27     | .27     | .27     |
| PERCENT                                    | 3.4   | 3.4   | 3.4   | 3.4    | 3.4     | 3.4     | 3.4     | 3.4     | 3.4     | 3.4     | 3.4     | 3.4     |
| MEAN SPEED                                 | 1.33  | 1.33  | 1.33  | 1.33   | 1.33    | 1.33    | 1.33    | 1.33    | 1.33    | 1.33    | 1.33    | 1.33    |
| MIN SPEED                                  | .48   | .48   | .48   | .48    | .48     | .48     | .48     | .48     | .48     | .48     | .48     | .48     |
| MAX SPEED                                  | 8.63  | 8.63  | 8.63  | 8.63   | 8.63    | 8.63    | 8.63    | 8.63    | 8.63    | 8.63    | 8.63    | 8.63    |
| STD. DEV.                                  | 1.22  | 1.22  | 1.22  | 1.22   | 1.22    | 1.22    | 1.22    | 1.22    | 1.22    | 1.22    | 1.22    | 1.22    |
| PERCENT                                    | 5.9   | 5.9   | 5.9   | 5.9    | 5.9     | 5.9     | 5.9     | 5.9     | 5.9     | 5.9     | 5.9     | 5.9     |
| MEAN SPEED                                 | 3.91  | 3.91  | 3.91  | 3.91   | 3.91    | 3.91    | 3.91    | 3.91    | 3.91    | 3.91    | 3.91    | 3.91    |
| MIN SPEED                                  | .75   | .75   | .75   | .75    | .75     | .75     | .75     | .75     | .75     | .75     | .75     | .75     |
| MAX SPEED                                  | 18.20 | 18.20 | 18.20 | 18.20  | 18.20   | 18.20   | 18.20   | 18.20   | 18.20   | 18.20   | 18.20   | 18.20   |
| STD. DEV.                                  | 4.47  | 4.47  | 4.47  | 4.47   | 4.47    | 4.47    | 4.47    | 4.47    | 4.47    | 4.47    | 4.47    | 4.47    |
| PERCENT                                    | 18.2  | 18.2  | 18.2  | 18.2   | 18.2    | 18.2    | 18.2    | 18.2    | 18.2    | 18.2    | 18.2    | 18.2    |
| MEAN SPEED                                 | 3.39  | 3.39  | 3.39  | 3.39   | 3.39    | 3.39    | 3.39    | 3.39    | 3.39    | 3.39    | 3.39    | 3.39    |
| MIN SPEED                                  | .23   | .23   | .23   | .23    | .23     | .23     | .23     | .23     | .23     | .23     | .23     | .23     |
| MAX SPEED                                  | 21.47 | 21.47 | 21.47 | 21.47  | 21.47   | 21.47   | 21.47   | 21.47   | 21.47   | 21.47   | 21.47   | 21.47   |
| STD. DEV.                                  | 3.78  | 3.78  | 3.78  | 3.78   | 3.78    | 3.78    | 3.78    | 3.78    | 3.78    | 3.78    | 3.78    | 3.78    |
| PERCENT                                    | 16.6  | 16.6  | 16.6  | 16.6   | 16.6    | 16.6    | 16.6    | 16.6    | 16.6    | 16.6    | 16.6    | 16.6    |
| MEAN SPEED                                 | 2.26  | 2.26  | 2.26  | 2.26   | 2.26    | 2.26    | 2.26    | 2.26    | 2.26    | 2.26    | 2.26    | 2.26    |
| MIN SPEED                                  | .63   | .63   | .63   | .63    | .63     | .63     | .63     | .63     | .63     | .63     | .63     | .63     |
| MAX SPEED                                  | 9.72  | 9.72  | 9.72  | 9.72   | 9.72    | 9.72    | 9.72    | 9.72    | 9.72    | 9.72    | 9.72    | 9.72    |
| STD. DEV.                                  | 1.91  | 1.91  | 1.91  | 1.91   | 1.91    | 1.91    | 1.91    | 1.91    | 1.91    | 1.91    | 1.91    | 1.91    |
| PERCENT                                    | 6.0   | 6.0   | 6.0   | 6.0    | 6.0     | 6.0     | 6.0     | 6.0     | 6.0     | 6.0     | 6.0     | 6.0     |
| MEAN SPEED                                 | 1.47  | 1.47  | 1.47  | 1.47   | 1.47    | 1.47    | 1.47    | 1.47    | 1.47    | 1.47    | 1.47    | 1.47    |
| MIN SPEED                                  | .81   | .81   | .81   | .81    | .81     | .81     | .81     | .81     | .81     | .81     | .81     | .81     |
| MAX SPEED                                  | 3.40  | 3.40  | 3.40  | 3.40   | 3.40    | 3.40    | 3.40    | 3.40    | 3.40    | 3.40    | 3.40    | 3.40    |
| STD. DEV.                                  | .72   | .72   | .72   | .72    | .72     | .72     | .72     | .72     | .72     | .72     | .72     | .72     |

SPEED 0 2 4 6 8 10 12 14 16 18 20  
CR/S 2 4 6 8 10 12 14 16 18 20 22

PERCENT 73.4 11.7 4.6 2.6 2.0 1.7 1.2 1.2 .5 .2 .1  
MEAN 814 192 205 209 207 245 207 257 267 296 297 301  
STD DEV 103 103 110 114 88 95 91 87 52 65 65 61

## SUMMARY STATISTICS

MEAN SPEED = 2.48 CM/S MINIMUM = 21.47 CM/S RANGE = 21.24 CM/S  
STANDARD DEVIATION = 3.01 CM/S SKEWNESS = 3.00

IN A COORDINATE SYSTEM WHOSE Y AXIS IS POSITIONED .00 DEGREES CLOCKWISE FROM TRUE NORTH  
MEAN X COMPONENT = -.49 CM/S STANDARD DEVIATION = 3.41 CM/S SKEWNESS = -1.41  
MEAN Y COMPONENT = .43 CM/S STANDARD DEVIATION = 2.02 CM/S SKEWNESS = 1.33

June 6, 1985  
 Buoy "A"  
 42° 25.671N  
 70° 35.004W

No Date Available

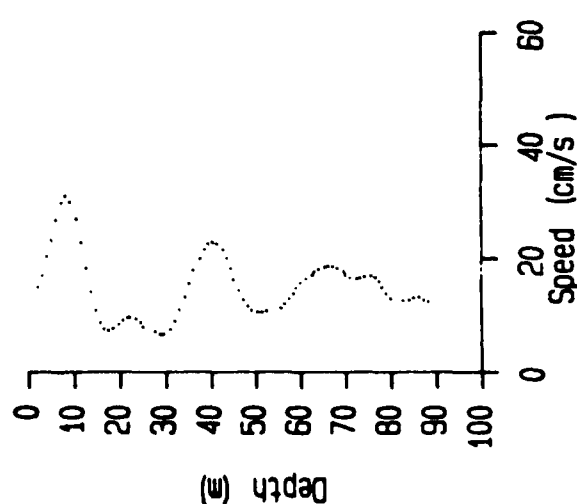
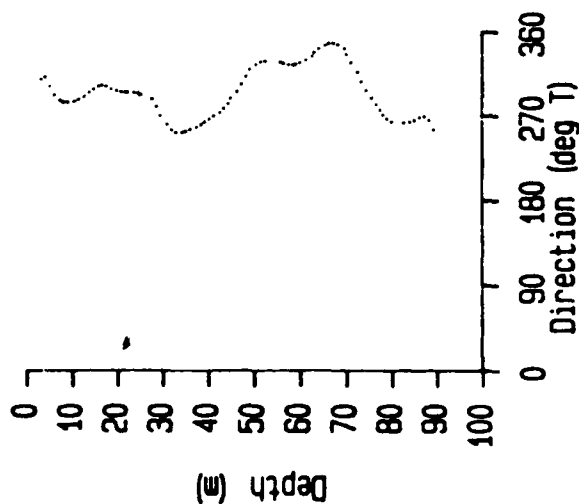
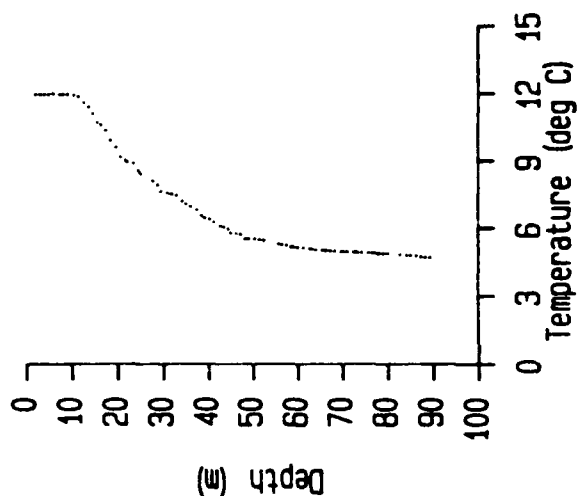
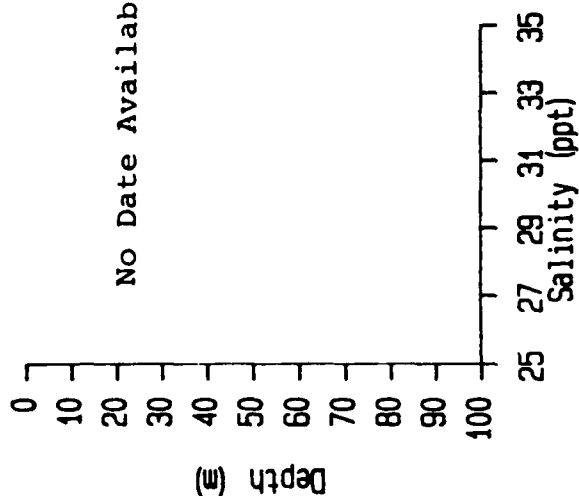


Figure I-1 Results of direct reading current meter casts at the Foul Area Disposal Site.

July 2, 1985  
 42° 25.647N  
 70° 34.413W

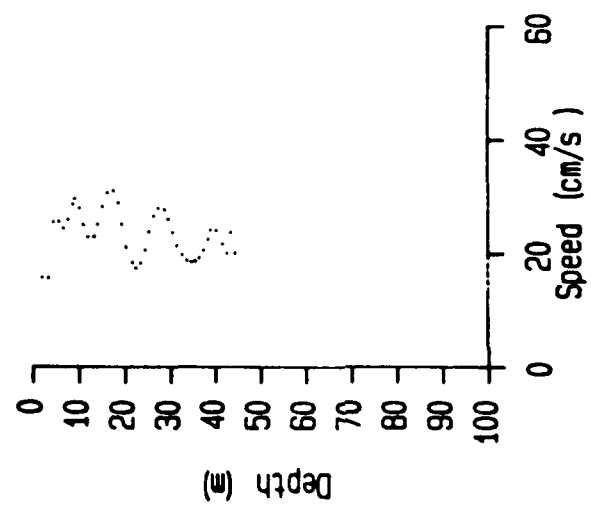
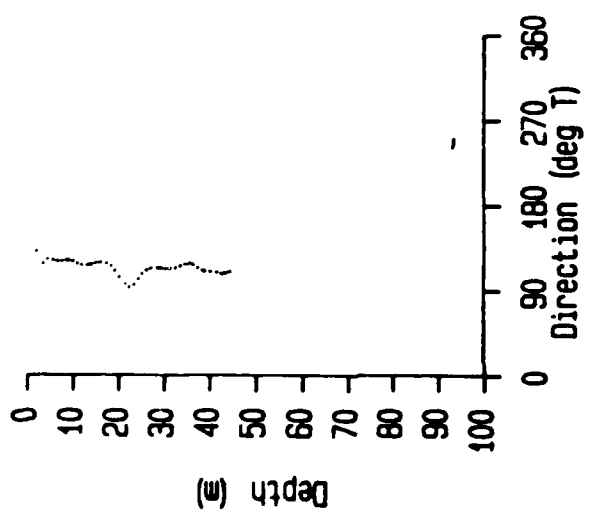
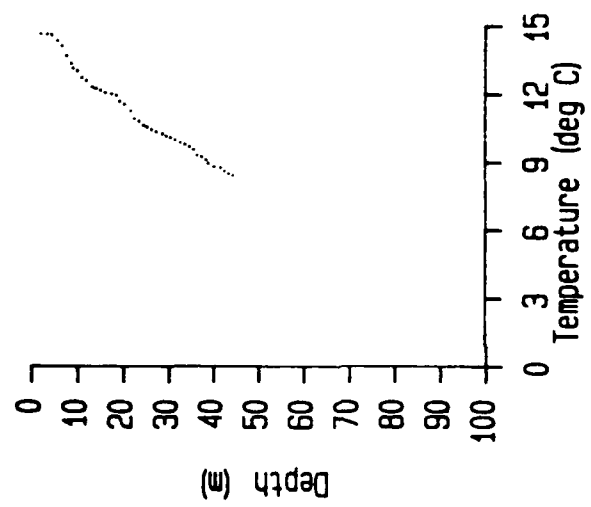
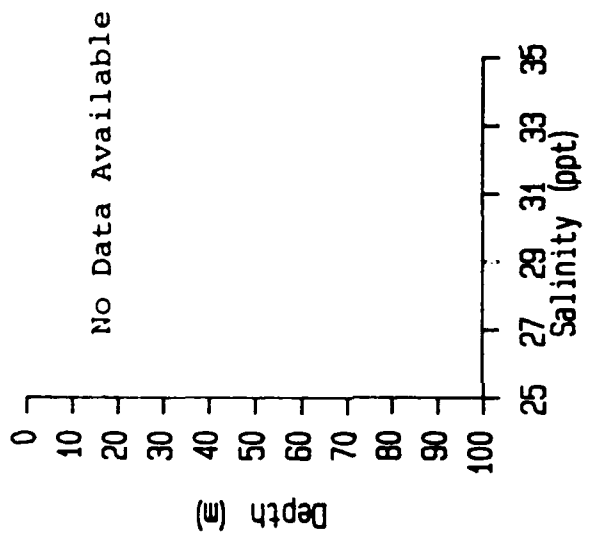


Figure I-1 continued

August 6, 1985  
Buoy "A"

42° 25.671N  
70° 35.004W

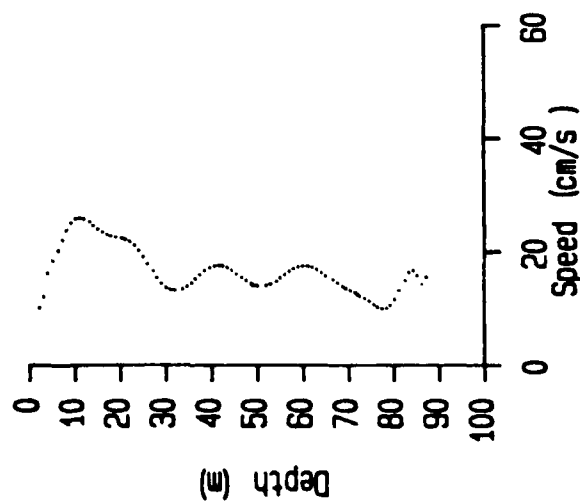
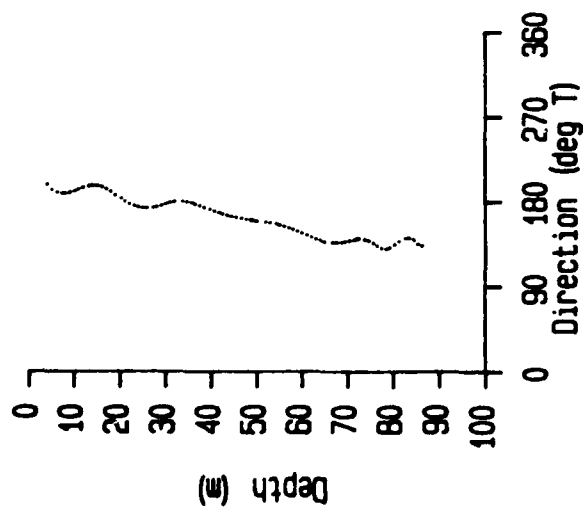
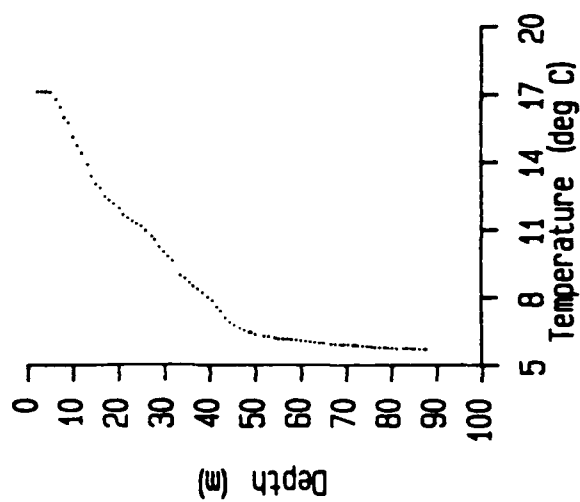
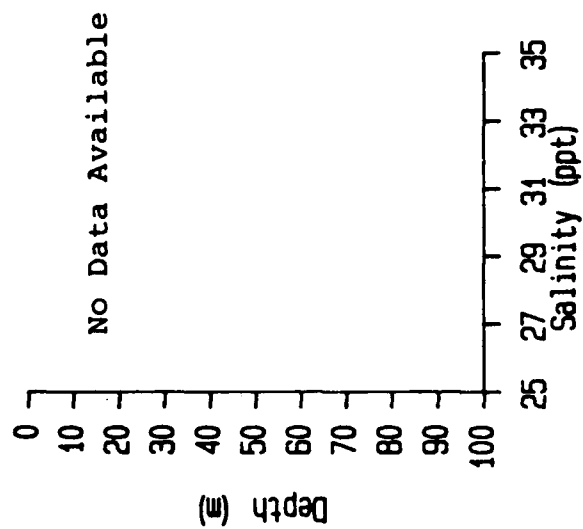


Figure I-1 continued



September 19, 1985

42° 25.993N

70° 34.926W

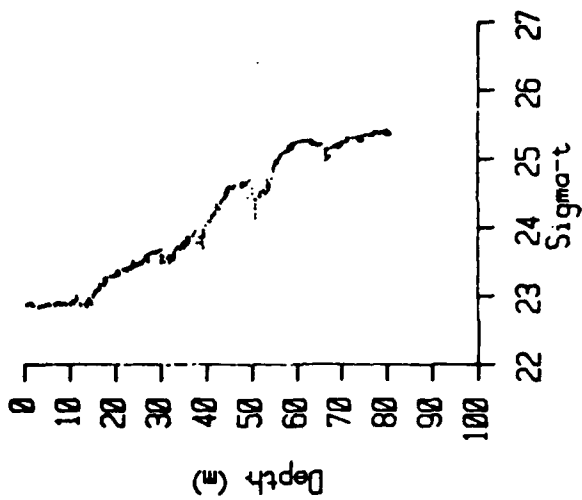
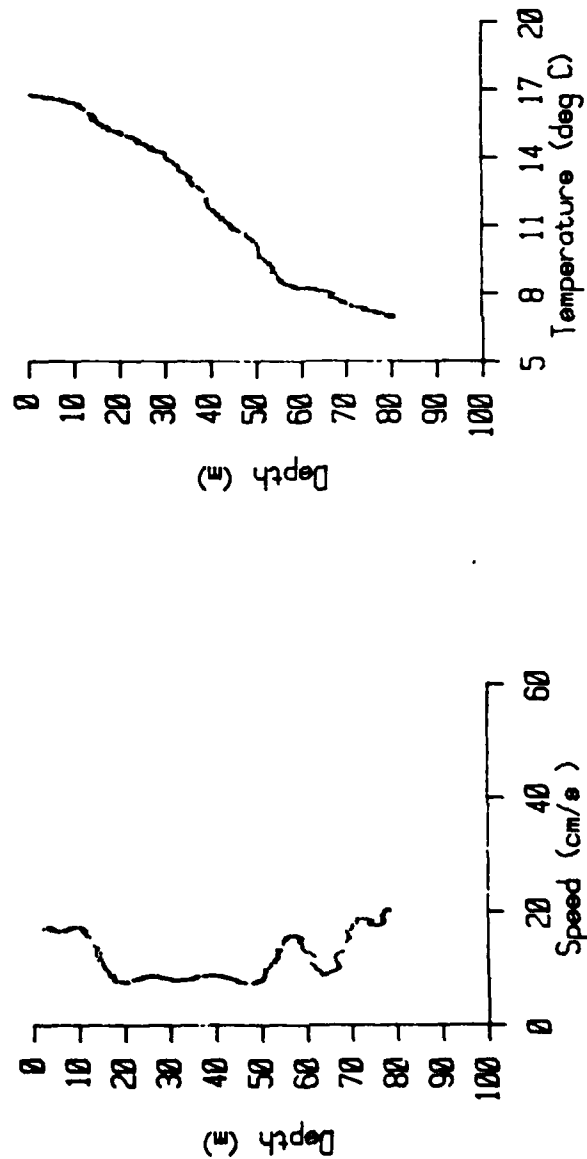
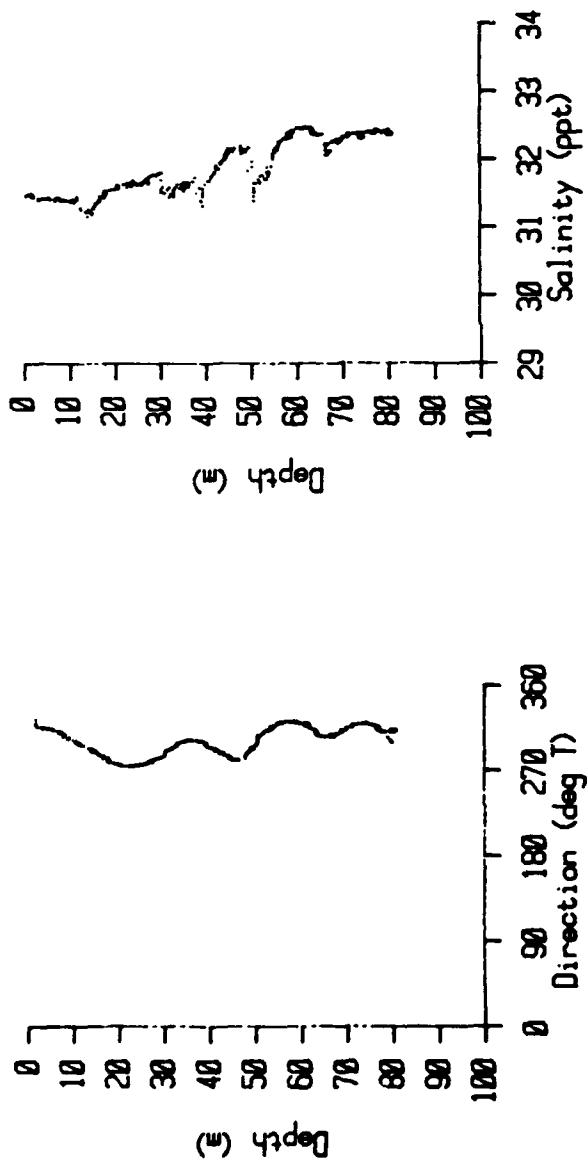


Figure I-1 continued

October 17, 1985

Cast # 1

Buoy "A"

42° 25.671N

70° 35.004W

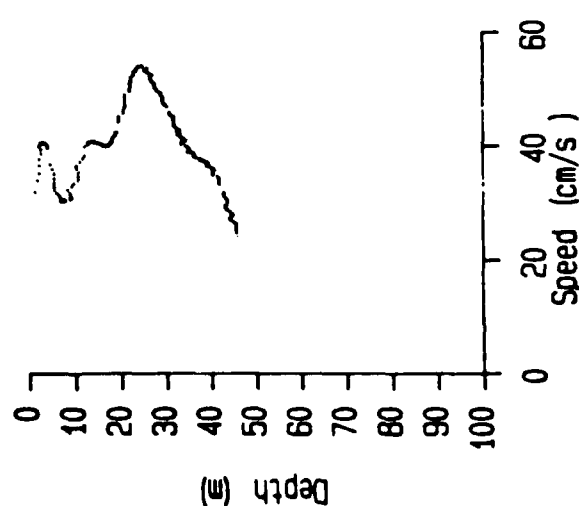
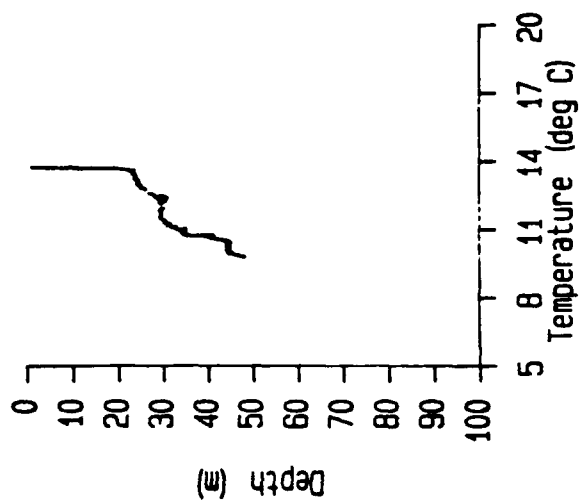
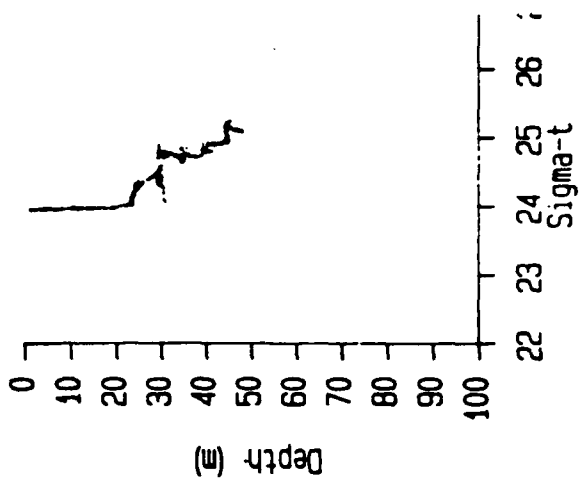
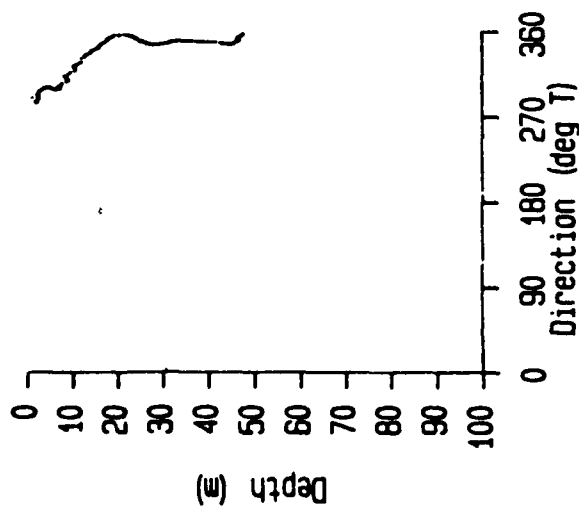
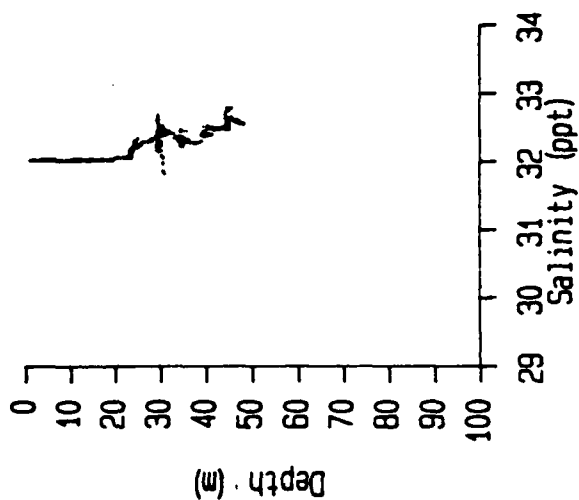


Figure I-1 continued

January 31, 1986

Cast # 2

Buoy "A"

42° 25.671N

70° 35.004W

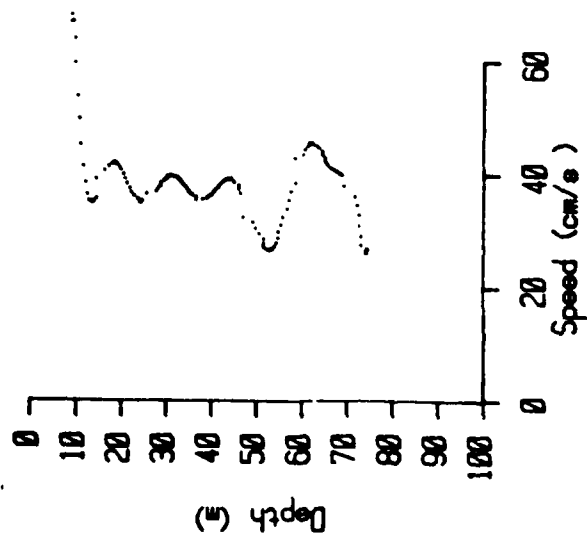
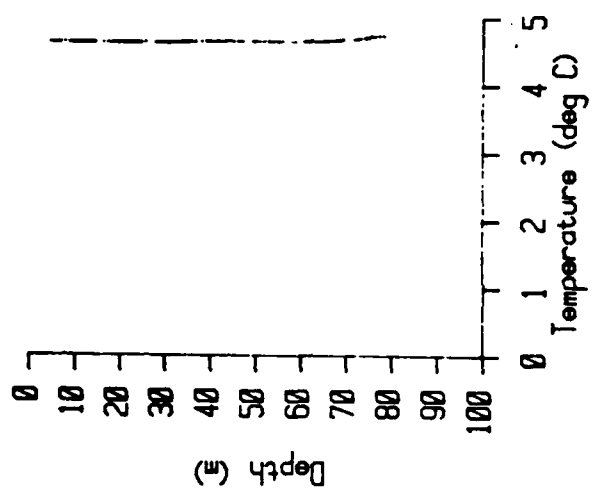
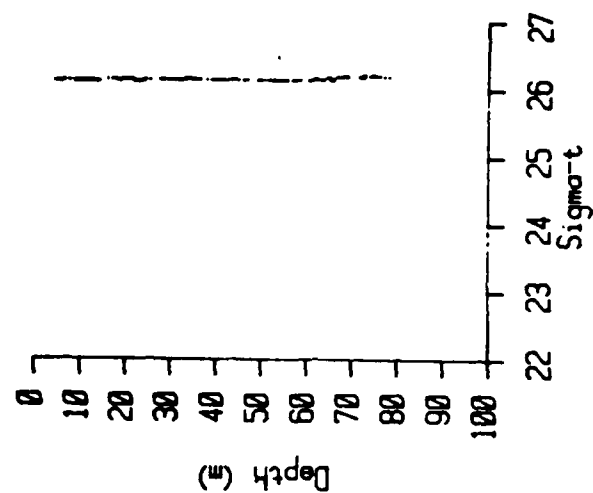
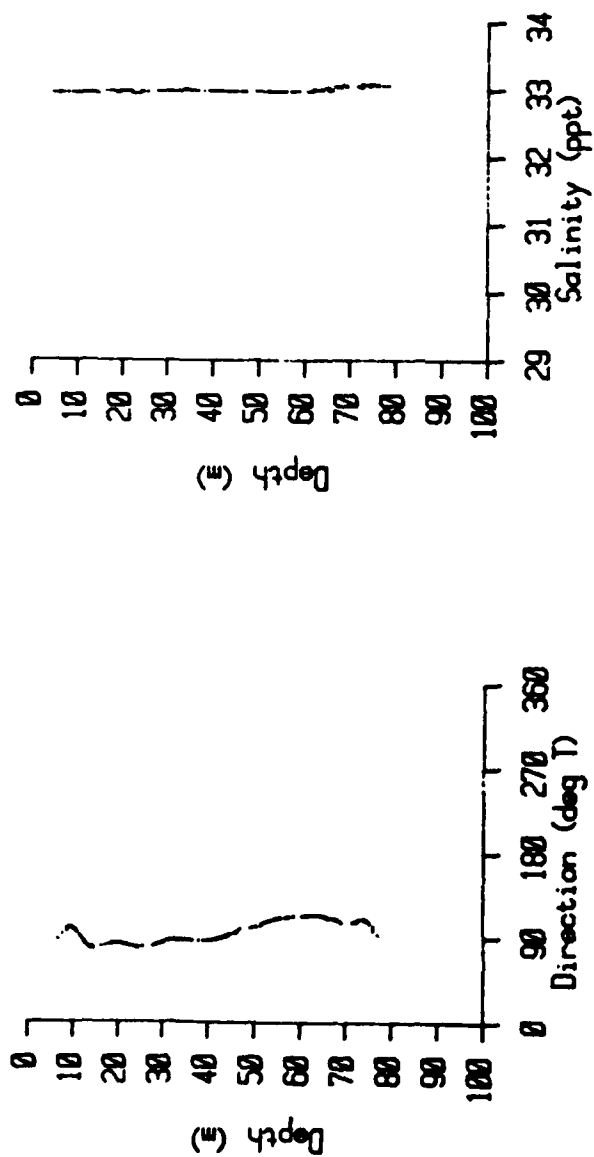


Figure I-1 continued

January 31, 1986

Cast # 3

Buoy "A"

42° 25.671N

70° 35.004W

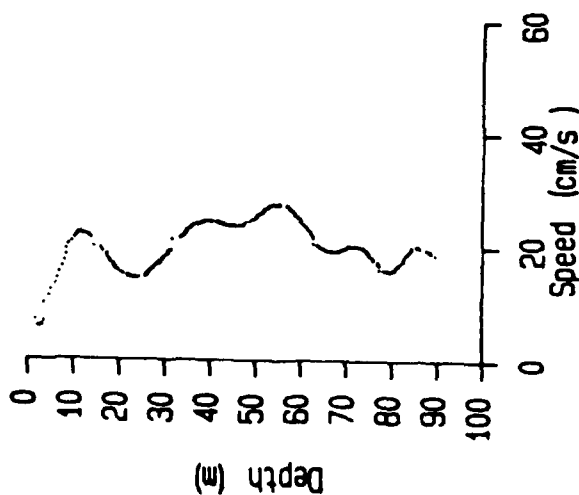
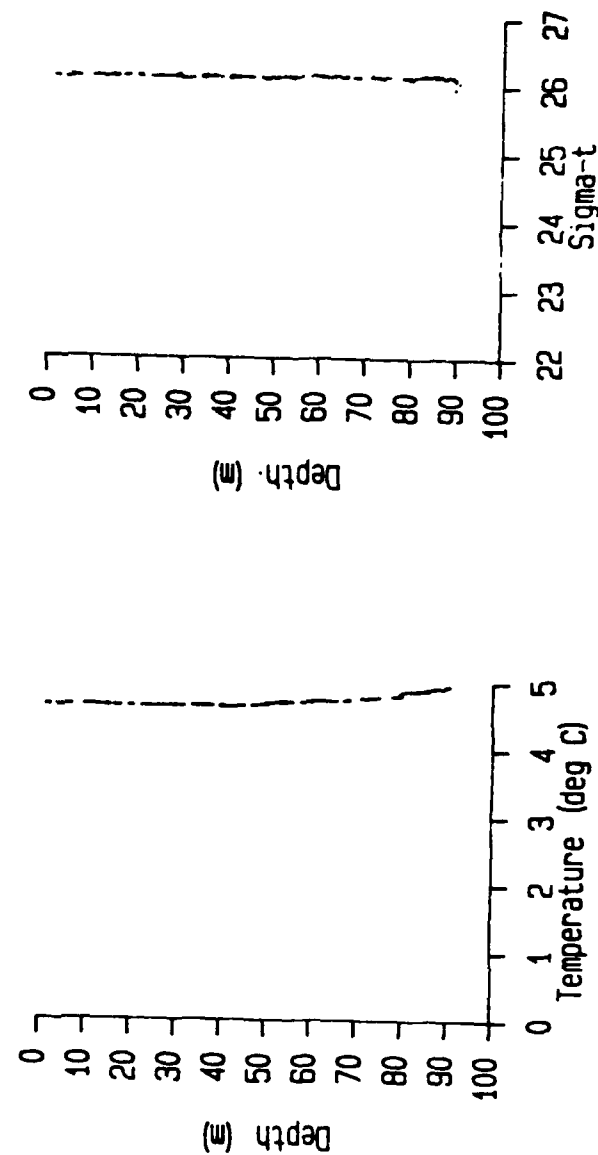
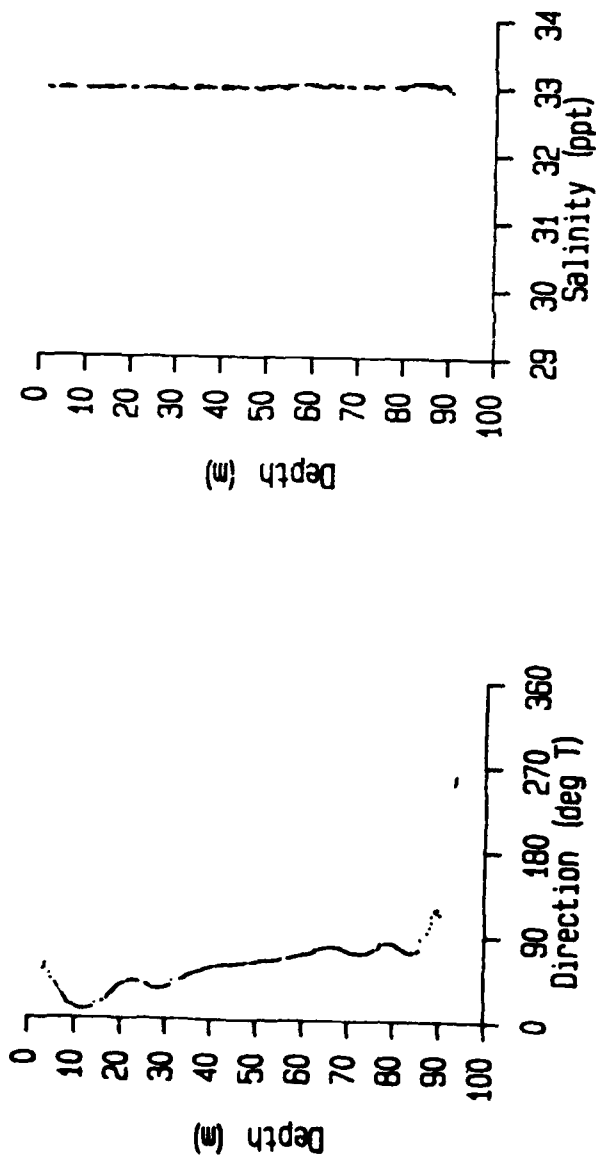


Figure I-1 continued

January 31, 1986

Cast # 4

Buoy "A"

42° 25.671N

70° 35.004W

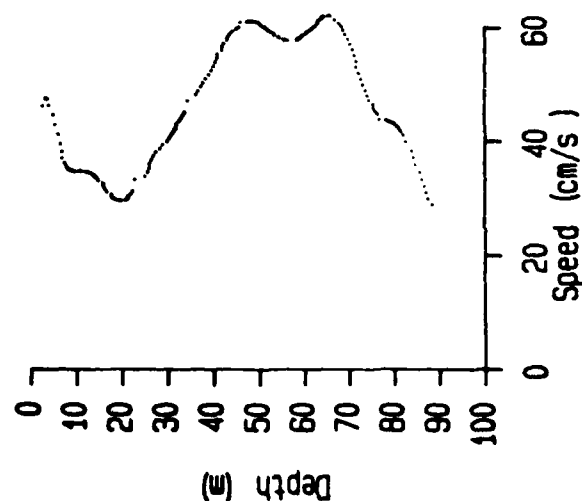
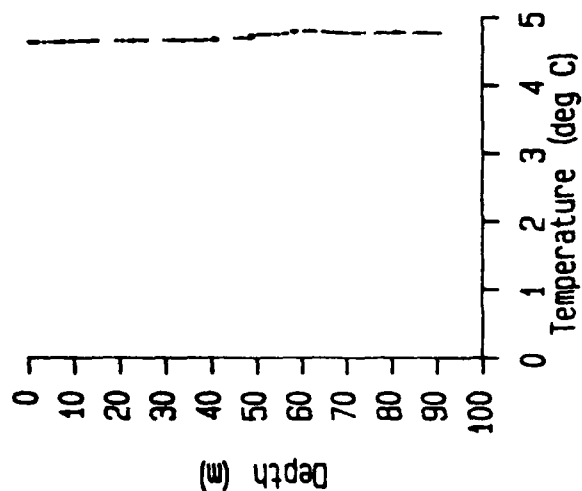
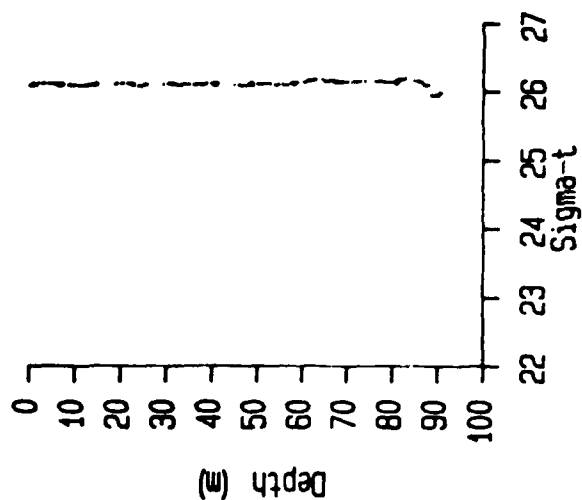
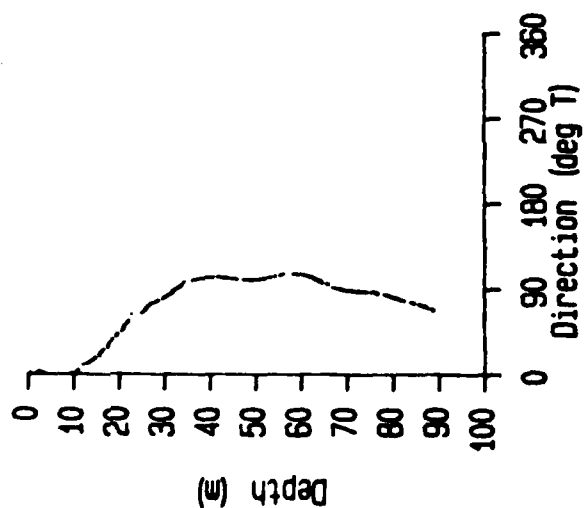
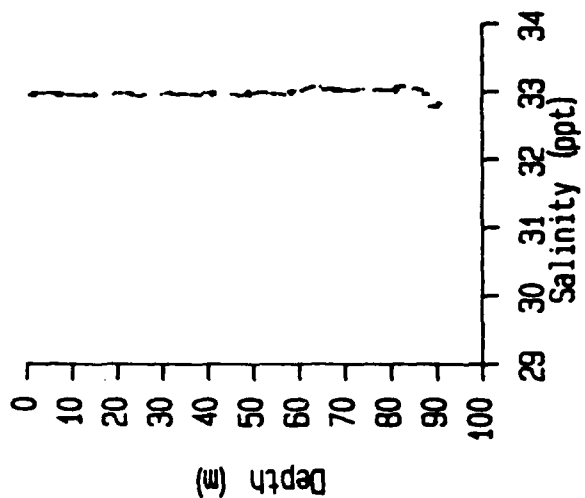


Figure I-1 continued

February 1, 1986

Cast # 5

Buoy "A"

42° 25.671N

70° 35.004W

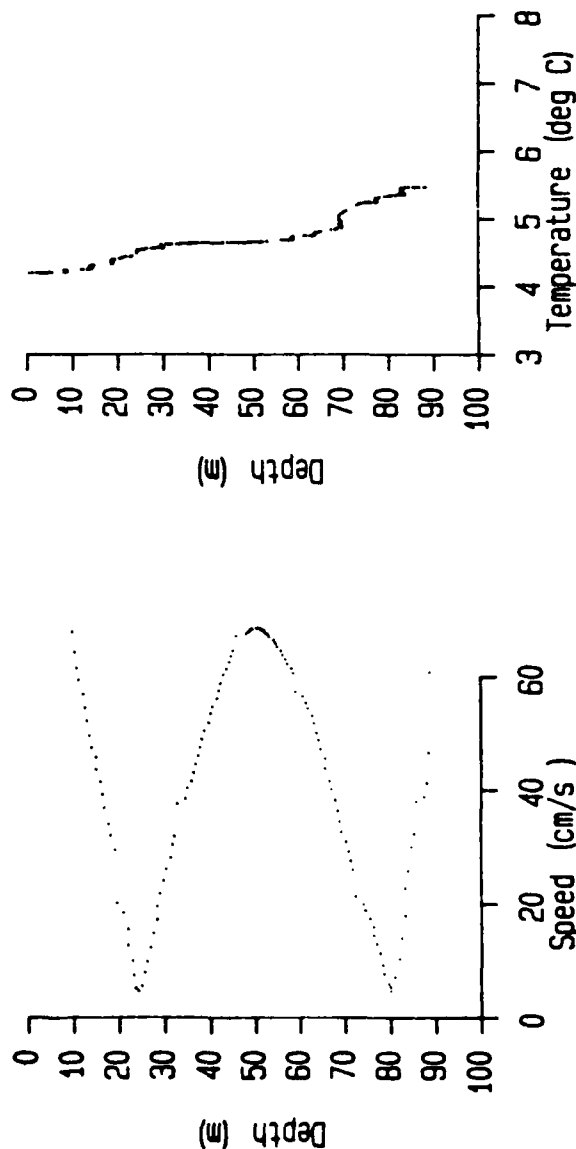
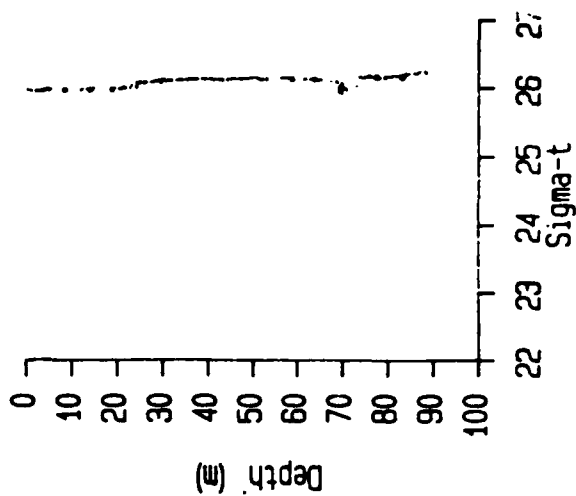
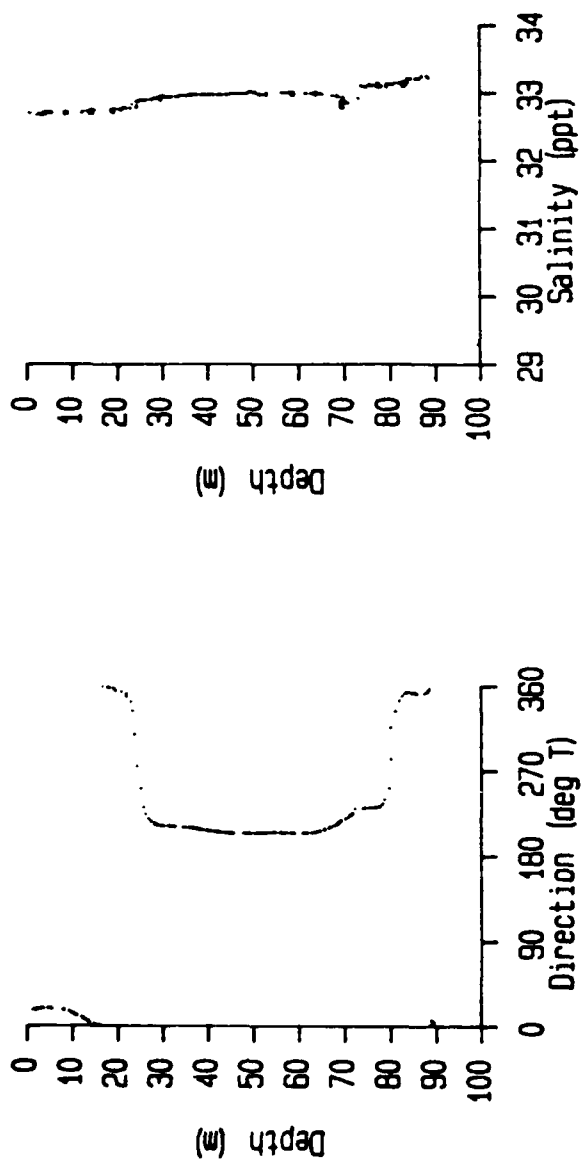


Figure I-1 continued

February 1, 1986  
 Cast # 6  
 "A" Buoy  
 42° 25.671N  
 70° 35.004W

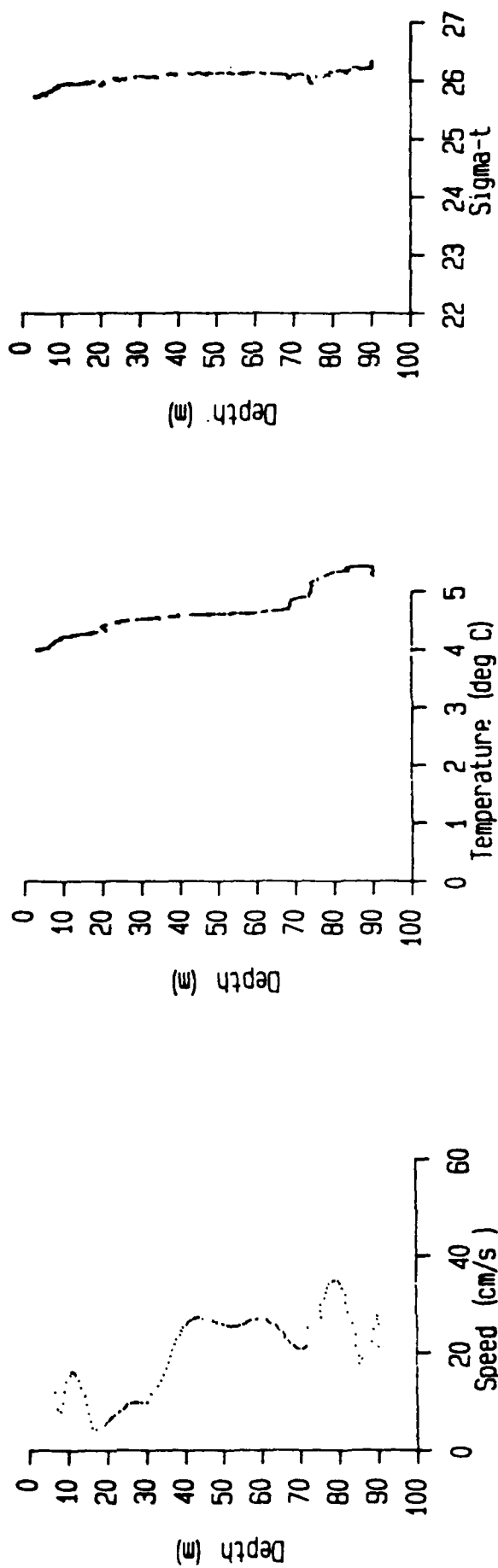
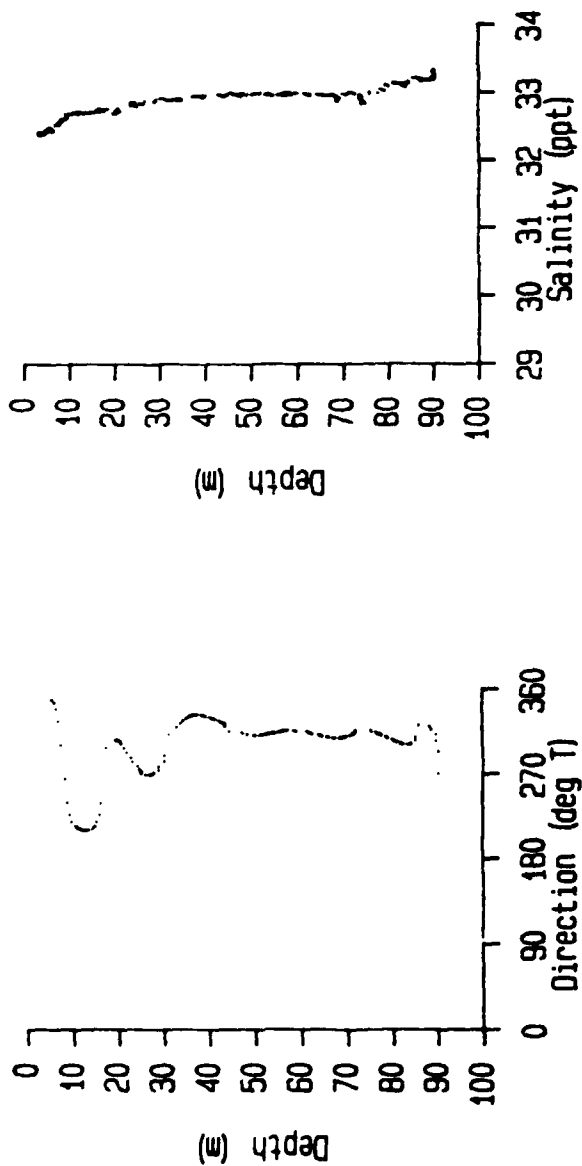


Figure I-1 continued

February 14, 1986

42° 25.400N

70° 32.505W

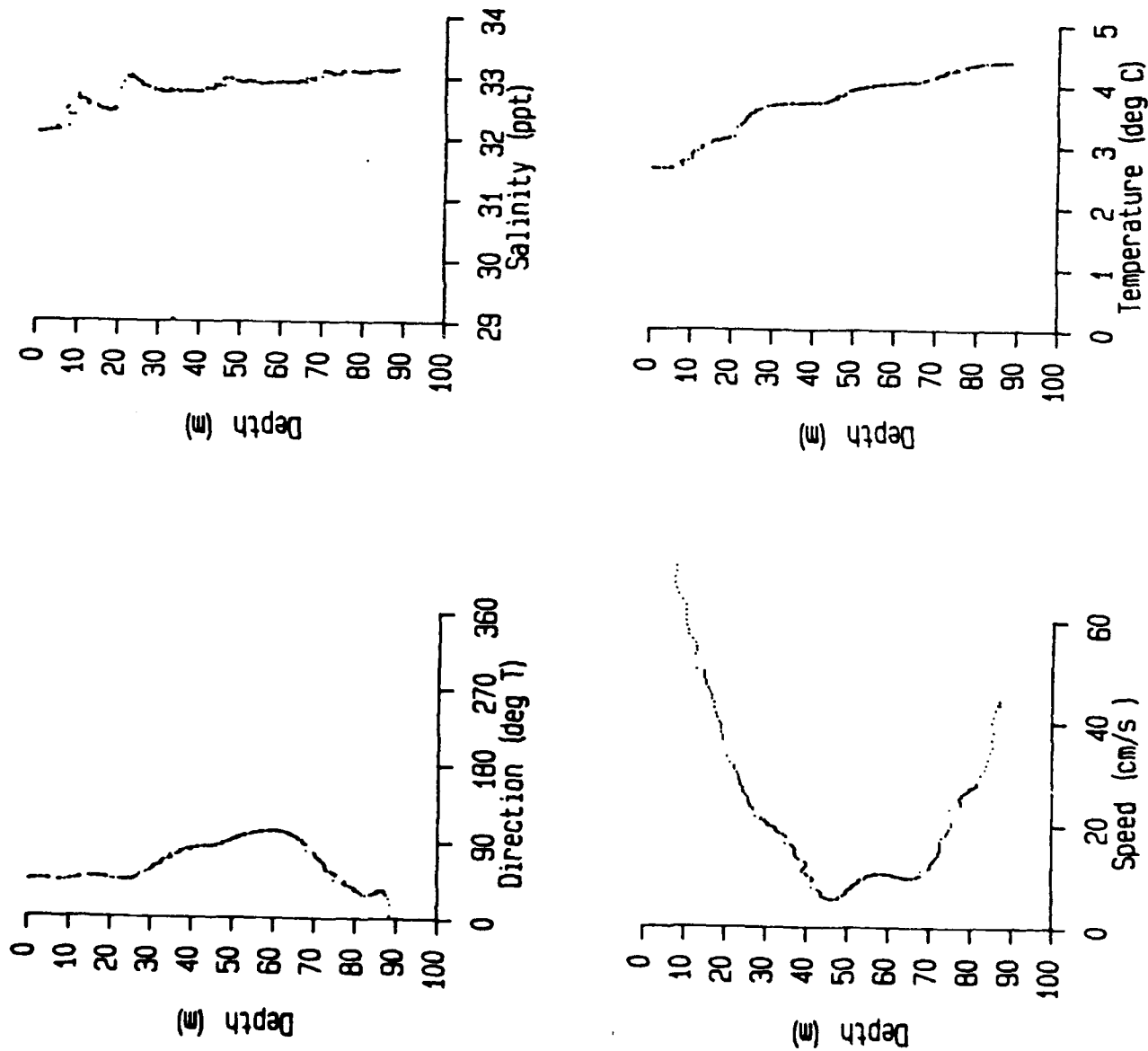


Figure I-1 continued



April 2, 1986  
Buoy "A"

42° 25.671N  
70° 35.004W

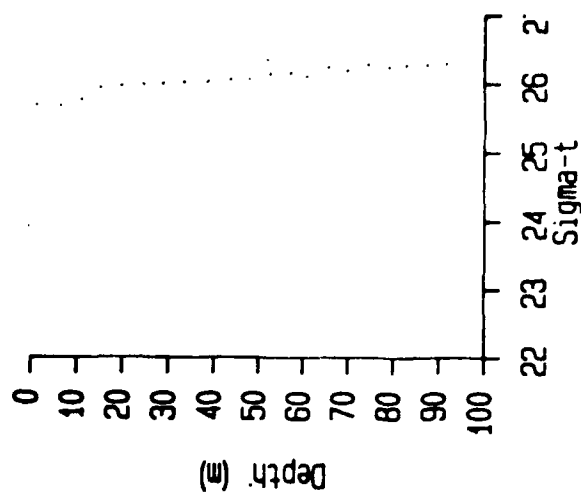
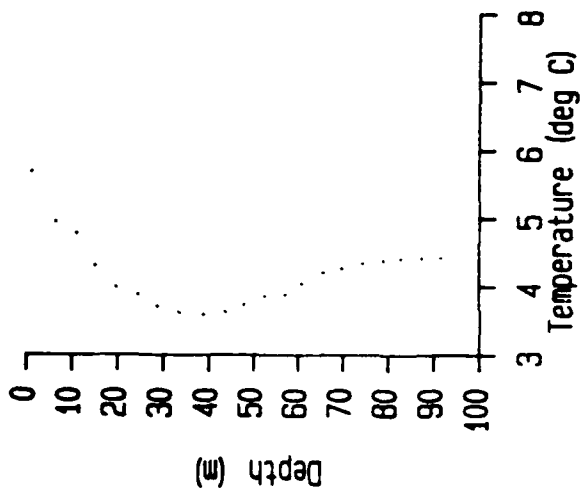
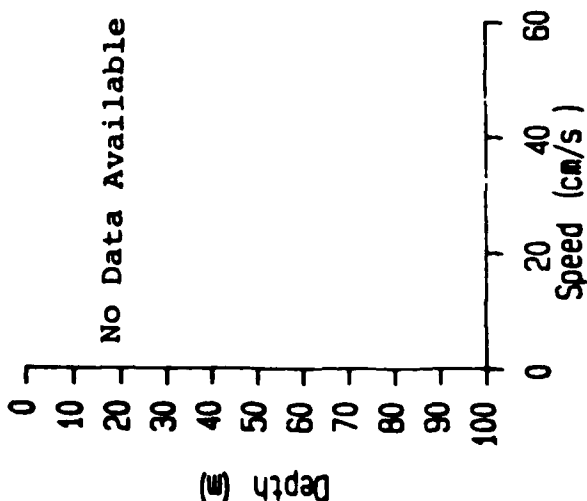
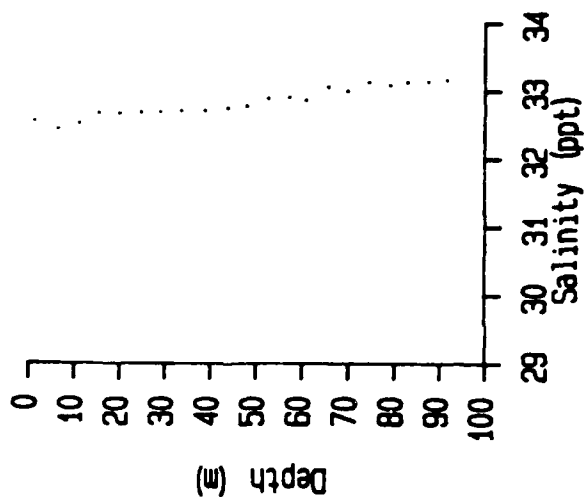
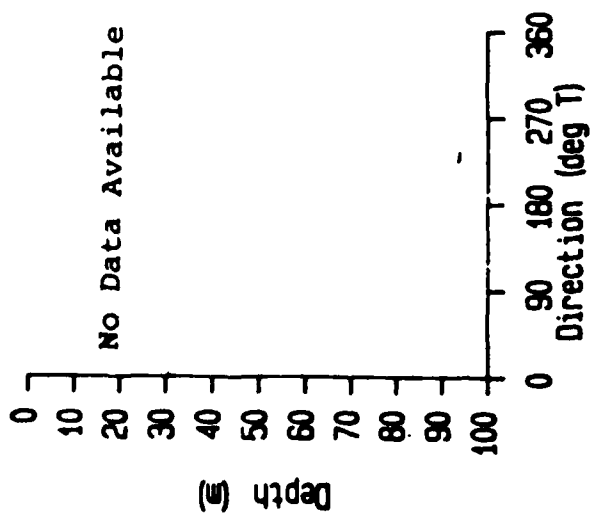


Figure I-1 continued

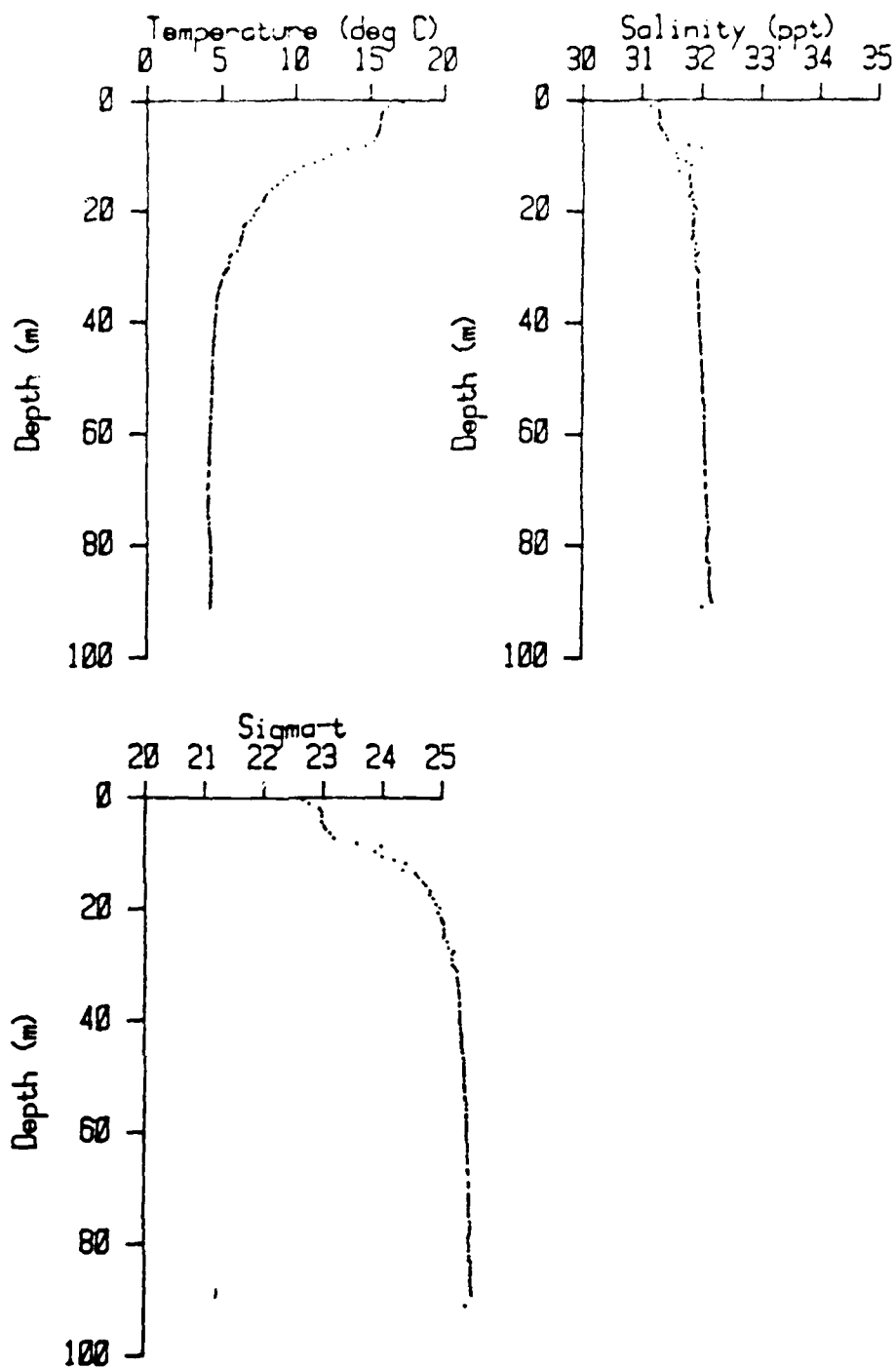


Figure I-2 Results of CTD cast at the Foul Area, 1 September 1987

APPENDIX II

Table II-A1 Results of Chemical Analysis - Boston Foul Grounds  
Arranged From West to East  
July, 1982

| Location | PPM<br>X10-5<br>COD | Volatile<br>Solids<br>NED | PPM<br>C:N Hg | PPM<br>As | PPM<br>Pb | PPM<br>Zn | PPM<br>X10-4<br>Fe | PPM<br>Cr | PPM<br>Cu | PPM<br>Mg | PPM<br>Ca | Mg:Ca | PPM<br>NH <sub>3</sub> |
|----------|---------------------|---------------------------|---------------|-----------|-----------|-----------|--------------------|-----------|-----------|-----------|-----------|-------|------------------------|
| BF18     | 102,000             | 4.8                       | 16.3          | 0.13      | 14        | 100       | 240                | 42        | 38        | 6,300     | 300       | 21.0  | 231                    |
| BF17     | 76,472              | 3.9                       | 16.6          | 0.14      | 12        | 150       | 270                | 45        | 55        | 6,600     | 680       | 9.7   | 57                     |
| BF21     | 48,800              | 4.5                       | 14.2          | 0.07      | 12        | 30        | 150                | 38        | 21        | 6,700     | 170       | 39.4  | 23                     |
| BF19     | 128,000             | 5.5                       | 17.5          | 0.20      | 19        | 31        | 260                | 39        | 39        | 7,200     | 1,900     | 3.8   | 29                     |
| BF7      | 100,460             | 4.7                       | 16.1          | 0.24      | 12        | 190       | 210                | 60        | 65        | 6,600     | 280       | 23.7  | 52                     |
| BF16     | 77,343              | 3.8                       | 15.4          | 0.12      | 10        | 100       | 190                | 38        | 36        | 5,200     | 160       | 32.5  | 170                    |
| BF20     | 84,500              | 3.2                       | 13.6          | 0.07      | 13        | 57        | 140                | 45        | 31        | 6,800     | 220       | 30.5  | 31                     |
| BF9(REF) | 76,000              | 4.7                       | 10.3 *        | 19        | 51        | 170       | 1.10               | 64        | 21        | 5,900     | 360       | 16.4  | 136                    |
| REF-#1   | 90,300              | 4.7                       | 10.1          | 17        | 59        | 200       | 1.60               | 75        | 25        | 7,800     | 470       | 16.5  | 39                     |
| REF-#2   | 73,700              | 4.6                       | 10.2          | 22        | 23        | 99        | 1.40               | 72        | 21        | 7,600     | 350       | 21.7  | 67                     |
| REF-#3   | 58,500              | 4.2                       | 10.8          | 18        | *         | 190       | 1.00               | 61        | 17        | 6,100     | 330       | 12.5  | 55                     |
| REF-#4   | 48,700              | 3.8                       | 10.0          | 18        | 24        | 150       | 1.20               | 67        | 19        | 7,100     | 330       | 21.5  | 38                     |
| REF-#5   | 52,000              | 4.5                       | 9.9           | 17        | 28        | 150       | 1.30               | 72        | 20        | 7,000     | 330       | 21.2  | 337                    |

\*below minimum detection limit.

Table II A-2 North-South Transect Near 70°34'.0 - BFG April 1983

| Location           | %<br>Volatiles<br>NED | ppm-5<br>CODx10 <sup>-5</sup> | ppm-4<br>Fe x 10 <sup>-4</sup> | C:N  | Mg:Cr | ppm<br>Oil & Grease | ppm<br>Cr | ppm<br>Zn | ppm<br>Cu | ppm<br>As |
|--------------------|-----------------------|-------------------------------|--------------------------------|------|-------|---------------------|-----------|-----------|-----------|-----------|
| 1000N-850E<br>3051 | 1.71                  | 0.51                          | 2.07                           | 14.8 | 25.2  | 681                 | 37        | 179       | 39        | 9.0       |
| 500N-850E<br>3056  | 3.64                  | 0.73                          | 2.32                           | 11.7 | 10.4  | 761                 | 76        | 175       | 43        | 9.3       |
| 850E<br>3057       | 4.22                  | 0.93                          | 2.70                           | 10.1 | 26.8  | 1,210               | 90        | 196       | 43        | 10.0      |
| 500S-850E<br>3058  | 4.82                  | 0.48                          | 2.46                           | 9.2  | 24.6  | 201                 | 74        | 206       | 23        | 8.6       |
| 1000S-850E<br>3059 | 4.95                  | 0.79                          | 2.57                           | 9.1  | 26.8  | 282                 | 74        | 156       | 23        | 10.0      |

North-South Transect at 70°33.5

|                     |      |      |      |     |      |     |    |     |    |     |
|---------------------|------|------|------|-----|------|-----|----|-----|----|-----|
| 1000N-1850E<br>3052 | 0.72 | -    | 1.44 | -   | 3.4  | -   | 41 | 75  | 12 | -   |
| 500N-1850E<br>3053  | 2.90 | 0.54 | 2.19 | 9.3 | 23.1 | 170 | 61 | 124 | 20 | 7.6 |
| REF<br>3054         | 4.22 | 0.53 | 2.58 | 8.8 | 18.3 | 242 | 70 | 168 | 22 | 8.8 |
| 500S-1850E<br>3055  | 4.60 | 0.72 | 2.52 | 8.8 | 20.7 | 282 | 70 | 152 | 21 | 8.6 |

Table II A-3 East-West - BFG April 1983

| Location          | Volatiles<br>%<br>NED | ppm<br>CODx10 <sup>-5</sup> | ppm<br>Fe x 10 <sup>-4</sup> | C:N  | Mg:Ca | ppm<br>Oil & Grease | ppm<br>Cr | ppm<br>Zn | ppm<br>Cu | ppm<br>As |
|-------------------|-----------------------|-----------------------------|------------------------------|------|-------|---------------------|-----------|-----------|-----------|-----------|
| 400W<br>3065      | 2.22                  | 0.83                        | 2.09                         | 21.6 | 13.3  | 6,510               | 444       | 469       | 114       | 10.2      |
| 275W<br>3066      | 3.66                  | 0.81                        | 2.03                         | 12.4 | 5.0   | 1,830               | 225       | 266       | 100       | 5.4       |
| 150W<br>3063      | 4.39                  | 0.87                        | 2.08                         | 11.5 | 8.8   | 2,790               | 215       | 285       | 100       | 5.8       |
| 50W<br>3067       | 2.99                  | 0.74                        | 1.80                         | 13.0 | 4.9   | 1,840               | 176       | 168       | 81        | 5.2       |
| CTR<br>3049       | 1.65                  | 0.80                        | 2.21                         | 9.0  | 14.5  | 158                 | 38        | 92        | 17        | 5.0       |
| 850E<br>3057      | 4.22                  | 0.93                        | 2.70                         | 10.1 | 26.8  | 1,210               | 90        | 196       | 43        | 10.0      |
| 1850E-REF<br>3054 | 4.22                  | 0.53                        | 2.58                         | 8.8  | 18.3  | 242                 | 70        | 168       | 22        | 8.8       |

Bulk sediment metals and PCB data are expressed in ppm or ppb based on dry weight of sample.

**Table 11 A-4**  
Trace metal concentrations from NMFS surveys  
approximately 10 km SSW of MBDS disposal buoy (1979-1982).

| Parameter    | Average | S.D. | N  |
|--------------|---------|------|----|
| Cadmium ppm  | 0.27*   | 0.05 | 20 |
| Chromium ppm | 35.21   | 8.41 | 20 |
| Copper ppm   | 7.78    | 1.53 | 20 |
| Lead ppm     | 20.02   | 3.67 | 20 |
| Nickel ppm   | 11.04   | 2.43 | 20 |
| Zinc ppm     | 37.12   | 5.49 | 20 |

\*includes detection limits as values when less than detectable.

Table II A-5 National Marine Fisheries Service (NMFS) and Massachusetts Division of Marine Resources (MDMF) bottom trawls in the vicinity of MBDS (1979-1984).a

| Agency/Date   | Strata <sup>b</sup> | Depth<br>(m) | Distance <sup>c</sup><br>from MBDS | Latitude/Longitude<br>(degrees-minutes) |
|---------------|---------------------|--------------|------------------------------------|---|
| <b>NMFS</b>   |                     |              |                                    |   |
| Spring 1980 a | 26                  | 88           | 4.1                                | 42 22' N 70 31' W                       |
| Spring 1980 b | 26                  | 73           | 5.7                                | 42 20' N 70 34' W                       |
| Spring 1983   | 26                  | 73           | 2.8                                | 42 28' N 70 36' W                       |
| Summer 1981   | 66                  | 72           | 4.6                                | 42 25' N 70 40' W                       |
| Fall 1980 a   | 66                  | 63           | 3.9                                | 42 27' N 70 39' W                       |
| Fall 1980 b   | 26                  | 66           | 5.7                                | 42 20' N 70 34' W                       |
| Fall 1981     | 26                  | 83           | 6.0                                | 42 26' N 70 36' W                       |
| Fall 1983 a   | 26                  | 84           | 1.5                                | 42 27' N 70 36' W                       |
| Fall 1983 b   | 66                  | 64           | 4.9                                | 42 25' N 70 41' W                       |
| Winter 1982 a | 26                  | 80           | 3.0                                | 42 27' N 70 35' W                       |
| Winter 1982 b | 26                  | 78           | 4.6                                | 42 21' N 70 34' W                       |
| Winter 1983   | 26                  | 87           | 3.0                                | 42 25' N 70 38' W                       |
| <b>MDMF</b>   |                     |              |                                    |   |
| Spring 1979 a | 36                  | 73           | 4.3                                | 42 29' N 70 38' W                       |
| Spring 1979 b | 36                  | 75           | 4.5                                | 42 25' N 70 37' W                       |
| Spring 1981   | 36                  | 77           | 4.1                                | 42 25' N 70 40' W                       |
| Spring 1982 a | 36                  | 66           | 4.3                                | 42 29' N 70 37' W                       |
| Spring 1982 b | 36                  | 73           | 3.2                                | 42 27' N 70 38' W                       |
| Spring 1984   | 36                  | 75           | 3.5                                | 42 28' N 70 38' W                       |
| Fall 1978     | 36                  | 67           | 5.7                                | 42 30' N 70 39' W                       |
| Fall 1979 a   | 36                  | 77           | 4.3                                | 42 29' N 70 39' W                       |
| Fall 1979 b   | 36                  | 75           | 4.3                                | 42 26' N 70 40' W                       |
| Fall 1980     | 36                  | 68           | 5.4                                | 42 30' N 70 39' W                       |
| Fall 1981     | 36                  | 73           | 3.9                                | 42 25' N 70 39' W                       |
| Fall 1983 a   | 36                  | 65           | 5.1                                | 42 29' N 70 39' W                       |
| Fall 1983 b   | 36                  | 73           | 3.7                                | 42 28' N 70 38' W                       |
| Fall 1984     | 36                  | 71           | 5.0                                | 42 25' N 70 37' W                       |

a. NMFS trawls were during March-May and September-November; MDMF trawls were principally during May and September

b. sampling areas defined by NMFS and MDMF based on geographic location and water depth.

c. approximate distance (in nautical miles) of trawl starting point (NMFS) or approximate mid point (MDMF) from the center of MBDS.



Table II A-6 Data from NMFS and MDMF trawls in the vicinity of MBDS.

NMFS

|                     | Winter<br>N | 1982<br>WT | Winter<br>N | 1982<br>WT | Winter<br>N | 1983<br>WT |
|---------------------|-------------|------------|-------------|------------|-------------|------------|
| LITTLE SKATE        |             |            | 8           | 5.0        |             |            |
| ATLANTIC HERRING    | 96          | 4.2        |             |            |             |            |
| ALEWIFE             |             |            |             |            | 11          | 14.0       |
| BLUEBACK HERRING    |             |            |             |            | 1           | 0.1        |
| SILVER HAKE         | 11          |            | 88          | 2.0        | 14          | 0.4        |
| ATLANTIC COD        | 8           | 9.5        | 4           | 7.5        | 3           | 7.0        |
| HADDOCK             | 1           |            |             |            | 25          | 4.4        |
| POLLOCK             | 1           | 0.3        |             |            | 157         | 9.3        |
| WHITE HAKE          |             |            | 1           | 0.2        |             |            |
| RED HAKE            |             |            |             |            | 7           | 0.4        |
| AMERICAN PLAICE     | 553         | 53.0       | 166         | 22.5       | 534         | 62.0       |
| YELLOWTAIL FLOUNDER | 2           | 1.1        | 1           |            | 3           | 1.0        |
| WINTER FLOUNDER     | 67          | 26.5       | 9           | 5.0        | 16          | 7.1        |
| WITCH FLOUNDER      |             |            | 26          | 13.5       | 3           | 0.4        |
| LONGHORN SCULPIN    | 6           | 0.9        | 8           | 1.5        | 15          | 2.1        |
| SEA RAVEN           | 3           | 2.8        | 2           | 2.7        | 1           | 2.5        |
| ATLANTIC WOLFFISH   | 1           | 7.2        |             |            |             |            |
| OCEAN POUT          | 9           | 10.7       | 3           | 0.7        | 7           | 5.2        |
| GOLDEN REDFISH      | 2           | 0.2        | 17          | 9.2        | 1           | 0.6        |
| Total:              | 760         | 116.4      | 333         | 69.8       | 798         | 116.5      |

|                     | Spring<br>N | 1980a<br>WT | Spring<br>N | 1980b<br>WT | Spring<br>N | 1983<br>WT |
|---------------------|-------------|-------------|-------------|-------------|-------------|------------|
| THORNY SKATE        | 5           | 15.5        | 13          | 12.5        | 13          | 6.6        |
| SILVER HAKE         | 9           | 0.1         | 6           | 0.2         | 13          | 1.6        |
| ATLANTIC COD        | 2           | 29.0        | 5           | 25.0        | 8           | 24.7       |
| HADDOCK             | 7           | 4.5         |             |             | 1           | 0.1        |
| POLLOCK             |             |             |             |             | 1           | <0.1       |
| RED HAKE            | 6           | 0.6         | 1           | 0.6         | 6           | 1.3        |
| AMERICAN PLAICE     | 284         | 50.0        | 290         | 50.0        | 248         | 61.5       |
| FOURSPOT FLOUNDER   | 1           | 0.3         |             |             |             |            |
| YELLOWTAIL FLOUNDER | 3           | 0.6         | 11          | 4.5         | 3           | 1.6        |
| WINTER FLOUNDER     |             |             | 1           | 0.6         |             |            |
| WITCH FLOUNDER      | 124         | 29.0        | 16          | 6.2         | 36          | 14.8       |
| LONGHORN SCULPIN    |             |             |             |             | 26          | 4.9        |
| SEA RAVEN           |             |             | 1           | 0.2         | 11          | 6.7        |
| AMERICAN SAND LANCE | 62          | 0.2         |             |             |             |            |
| ATLANTIC WOLFFISH   |             |             |             |             | 1           | <0.1       |
| OCEAN POUT          |             |             | 3           | 2.0         | 12          | 7.8        |
| GOOSEFISH           |             |             | 1           | 7.5         | 1           | 2.7        |
| WINTER SKATE        |             |             |             |             | 3           | 15.3       |
| Total:              | 503         | 129.8       | 348         | 109.3       | 383         | 140.6      |

Table II A-7 continued.

## MDMF

|                     | Spring<br>N | Spring<br>WT | Spring<br>N | Spring<br>WT | Spring<br>N | Spring<br>WT | Spring<br>N | Spring<br>WT | Spring<br>N | Spring<br>WT |
|---------------------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|
| THORNY SKATE        |             |              | 2           | 3.4          |             |              | 1           | 0.1          |             |              |
| ATLANTIC HERRING    |             |              |             |              | 63          | 13.3         |             |              | 17          | 13.0         |
| ALEWIFE             |             |              |             |              |             |              | 4           | 0.1          | 15          | 0.7          |
| BLUEBACK HERRING    | 2           | <0.1         | 6           | 0.2          | 5           | 0.5          | 2           |              | 5           | 0.1          |
| SILVER HAKE         | 34          | 0.7          |             |              | 27          | 0.8          | 5           | 0.2          | 26          | 1.0          |
| ATLANTIC COD        | 2           | 0.2          | 87          | 44.6         | 4           | 5.3          | 14          | 6.1          | 2           | 1.5          |
| HADDOCK             |             |              | 1           | 1.4          |             |              |             |              |             |              |
| WHITE HAKE          | 30          | 2.4          | 18          | 1.0          |             |              | 2           | 0.1          | 8           | 0.2          |
| RED HAKE            | 17          | 2.3          |             |              | 17          | 4.3          | 1           | 0.1          | 8           | 1.3          |
| FOURBEARD ROCKLING  | 4           | 0.1          |             |              | 11          | 0.6          |             |              | 1           | 0.2          |
| AMERICAN PLAICE     | 1127        | 87.1         | 831         | 81.5         | 1342        | 88.8         | 903         | 76.8         | 2104        | 209.0        |
| FOURSPOT FLOUNDER   |             |              | 1           | 0.2          | 1           | 0.1          | 1           | 0.1          | 1           | 0.1          |
| YELLOWTAIL FLOUNDER | 6           | 3.8          | 10          | 5.1          | 2           | 1.1          | 10          | 4.7          | 4           | 0.8          |
| WINTER FLOUNDER     | 2           | 0.4          | 7           | 2.3          | 3           | 0.3          | 2           | 0.6          | 2           | 0.2          |
| WITCH FLOUNDER      | 4           | 2.4          | 10          | 7.6          | 2           | 0.1          | 1           | 0.4          | 2           | 0.3          |
| LONGHORN SCULPIN    | 4           | 0.5          | 22          | 3.0          | 1           | <0.1         | 48          | 4.3          | 14          | 1.3          |
| SEA RAVEN           | 1           | 0.1          | 5           | 6.3          |             |              | 1           | 0.4          | 3           | 4.5          |
| ALLIGATOR FISH      | 2           | <0.1         | 1           | <0.1         | 6           | <0.1         | 10          | 0.1          | 2           | <0.1         |
| SNAKEBLENY          | 40          | 1.2          |             |              | 168         | 11.1         | 1           | <0.1         | 5           | 0.1          |
| DAUBED SHANNY       | 10          | 0.1          | 22          | 0.1          | 105         | 0.5          | 12          | 0.2          | 9           | 0.1          |
| ATLANTIC WOLFFISH   |             |              |             |              |             |              |             |              | 1           | 2.5          |
| OCEAN POUT          | 92          | 43.7         | 98          | 29.6         | 27          | 16.7         | 38          | 25.7         | 107         | 55.6         |
| GOOSEFISH           |             |              |             |              | 1           |              |             |              |             |              |
| REDFISH             |             |              |             |              |             |              |             |              | 1           | 0.1          |
| Total:              | 1377        | 145.0        | 1121        | 186.3        | 1785        | 143.6        | 1056        | 120.0        | 2318        | 279.4        |
|                     |             |              |             |              |             |              |             |              | 506         | 116.1        |

Table II A-8 continued.

NMFS

|                     | Fall<br>N | 1980a<br>WT | Fall<br>N | 1980b<br>WT | Fall<br>N | 1981<br>WT |
|---------------------|-----------|-------------|-----------|-------------|-----------|------------|
| THORNY SKATE        |           |             |           | 9 41.0      |           |            |
| ATLANTIC HERRING    |           |             |           |             |           |            |
| ALEWIFE             | 18        | 4.0         | 390       | 83.0        | 7         | 1.7        |
| SILVER HAKE         | 126       | 11.5        | 62        | 6.6         | 61        | 10.0       |
| ATLANTIC COD        | 2         | 2.5         | 151       | 171.0       | 1         | 0.2        |
| HADDOCK             | 2         | 0.1         | 1         | 0.0         | 1         | 0.2        |
| POLLOCK             |           |             |           |             |           |            |
| WHITE HAKE          | 4         | 1.5         | 1         | 0.1         | 3         | 1.5        |
| RED HAKE            | 8         | 3.0         | 23        | 13.5        | 39        | 21.5       |
| CUSK                |           |             | 1         | 0.5         |           |            |
| AMERICAN PLAICE     | 176       | 16.5        | 103       | 27.0        | 121       | 20.0       |
| YELLOWTAIL FLOUNDER |           |             | 5         | 2.4         |           |            |
| WINTER FLOUNDER     |           |             | 2         | 0.9         |           |            |
| WITCH FLOUNDER      | 12        | 8.5         | 6         | 6.5         | 1         | 0.2        |
| ATLANTIC MACKEREL   |           |             | 1         | 0.7         |           |            |
| BUTTERFISH          | 3         | 0.1         | 4         | 0.4         |           |            |
| SCUP                | 1         | 0.2         |           |             |           |            |
| GOLDEN REDFISH      | 3         | 0.5         | 59        | 22.7        |           |            |
| LONGHORN SCULPIN    | 1         | 0.2         | 7         | 2.0         | 1         | 0.1        |
| SEA RAVEN           | 4         | 2.0         | 5         | 6.1         | 3         | 1.7        |
| CUNNER              |           |             | 27        | 4.1         | 3         | 0.5        |
| ATLANTIC WOLFFISH   |           |             | 1         | 1.0         |           |            |
| OCEAN POUT          | 17        | 9.5         | 19        | 8.9         | 7         | 2.5        |
| GOOSEFISH           | 1         | 10.0        | 1         | 20.0        | 1         | 3.5        |
| SPINY DOGFISH       |           |             |           |             |           |            |
| Total:              | 378       | 70.1        | 878       | 418.4       | 249       | 63.6       |

NMFS

|                     | Fall<br>N | 1983a<br>WT | Fall<br>N | 1983b<br>WT |
|---------------------|-----------|-------------|-----------|-------------|
| THORNY SKATE        | 2         | 2.8         |           |             |
| ATLANTIC HERRING    |           |             | 8         | 2.2         |
| ALEWIFE             | 10        | 2.3         | 34        | 9.5         |
| SILVER HAKE         | 44        | 6.5         | 63        | 10.8        |
| ATLANTIC COD        | 10        | 12.2        | 3         | 6.8         |
| HADDOCK             |           |             |           |             |
| POLLOCK             | 8         | 1.6         |           |             |
| WHITE HAKE          |           |             |           |             |
| RED HAKE            | 8         | 3.4         | 7         | 6.6         |
| CUSK                |           |             |           |             |
| AMERICAN PLAICE     | 11        | 2.0         | 148       | 26.5        |
| YELLOWTAIL FLOUNDER |           |             |           |             |
| WINTER FLOUNDER     |           |             | 4         | 1.4         |
| WITCH FLOUNDER      | 7         | 5.4         |           |             |
| ATLANTIC MACKEREL   |           |             | 1         | 0.5         |
| BUTTERFISH          |           |             |           |             |
| SCUP                |           |             |           |             |
| GOLDEN REDFISH      | 4         | 0.2         | 33        | 9.2         |
| LONGHORN SCULPIN    | 8         | 13.0        |           |             |
| SEA RAVEN           | 5         | 3.0         |           |             |
| CUNNER              | 1         | 0.2         |           |             |
| ATLANTIC WOLFFISH   |           |             | 31        | 9.0         |
| OCEAN POUT          | 5         | 1.5         | 2         | 1.0         |
| GOOSEFISH           |           |             |           |             |
| SPINY DOGFISH       |           |             | 1         | 1.5         |
| Total:              | 123       | 54.1        | 335       | 84.0        |

## MOMF

|                     | Fall<br>N | 1978<br>WT | Fall<br>N | 1979<br>WT | Fall<br>N | 1979<br>WT | Fall<br>N | 1980<br>WT |
|---------------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|
| THORNY SKATE        |           |            |           |            |           |            |           |            |
| ATLANTIC HERRING    | 101       | 2.5        |           |            | 1         | 1.4        | 1         | 0.5        |
| ALEWIFE             | 31        | 1.4        |           |            |           |            | 1         | <0.1       |
| SILVER HAKE         | 104       | 7.7        |           |            | 1         | 0.1        | 6         | 0.3        |
| ATLANTIC COD        |           |            | 306       | 18.6       | 215       | 19.1       | 48        | 1.7        |
| WHITE HAKE          | 21        | 4.5        |           |            | 3         | 5.0        |           |            |
| RED HAKE            | 55        | 24.0       | 14        | 5.2        | 8         | 3.4        | 15        | 1.9        |
| FOURBEARD ROCKLING  | 11        | 0.6        | 22        | 10.8       | 37        | 20.2       | 28        | 15.1       |
| AMERICAN PLAICE     | 400       | 17.7       |           |            | 1         | <0.1       | 2         | 0.1        |
| FOURSPOT FLOUNDER   |           |            | 84        | 13.2       | 464       | 58.0       | 330       | 14.9       |
| YELLOWTAIL FLOUNDER |           |            | 3         | 1.9        |           |            |           |            |
| WITCH FLOUNDER      | 1         | 0.6        |           |            | 1         | 0.7        |           |            |
| BUTTERFISH          | 5         | 3.2        | 6         | 1.8        | 55        | 32.2       | 4         | 1.7        |
| LONGHORN SCULPIN    | 9         | 0.2        |           |            |           |            | 1         | <0.1       |
| SEA RAVEN           |           |            |           |            | 2         | 0.3        |           |            |
| SNAKEBLENY          |           |            |           |            | 6         | 2.0        |           |            |
| WRYMOUTH            | 22        | 16.0       |           |            |           |            |           |            |
| OCEAN POUT          | 1         | 1.2        |           |            |           |            |           |            |
| GOOSEFISH           | 7         | 1.5        | 26        | 15.0       | 47        | 14.1       | 1         | 0.9        |
| Haddock             |           |            | 2         | 28.6       | 3         | 3.9        |           |            |
| Alligatorfish       |           |            |           |            |           |            | 2         | 0.2        |
| Total:              | 768       | 81.1       | 463       | 95.1       | 844       | 160.4      | 437       | 43.3       |

## MOMF

|                     | Fall<br>N | 1981<br>WT | Fall<br>N | 1983<br>WT | Fall<br>N | 1983<br>WT | Fall<br>N | 1984<br>WT |
|---------------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|
| THORNY SKATE        | 1         | 0.2        |           |            |           |            |           |            |
| ATLANTIC HERRING    | 1         |            |           |            | 2         | 0.5        | 4         | 5.2        |
| ALEWIFE             |           |            | 68        | 4.7        | 159       | 13.2       | 4         | 0.5        |
| BLUEBACK HERRING    |           |            | 9         | 0.6        | 6         | 0.4        | 4         | 0.1        |
| AMERICAN SHAD       |           |            | 2         | 0.1        | 2         | 0.1        |           |            |
| SILVER HAKE         |           |            | 4         | 0.5        | 5         | 0.7        |           |            |
| ATLANTIC COD        | 91        | 6.5        | 75        | 9.0        | 168       | 19.8       | 60        | 24.2       |
| POLLOCK             | 3         | 2.1        |           |            | 1         | 0.0        | 70        | 2.7        |
| WHITE HAKE          |           |            |           |            | 3         | 0.9        |           |            |
| RED HAKE            | 5         | 1.0        | 2         | 0.4        |           |            |           |            |
| FOURBEARD ROCKLING  | 22        | 9.0        | 246       | 85.6       | 102       | 51.6       | 58        | 28.5       |
| AMERICAN PLAICE     | 3         | 0.4        | 4         | 0.3        | 9         | 1.0        |           |            |
| FOURSPOT FLOUNDER   | 390       | 51.3       | 688       | 27.6       | 1224      | 63.9       | 473       | 50.4       |
| YELLOWTAIL FLOUNDER | 1         | 0.2        |           |            |           |            |           |            |
| WINTER FLOUNDER     |           |            |           |            | 1         | 0.6        |           |            |
| WITCH FLOUNDER      |           |            |           |            | 1         | 0.9        |           |            |
| WINDOWPANE          | 22        | 12.1       | 2         | 0.9        | 34        | 13.0       | 10        | 4.1        |
| BUTTERFISH          |           |            |           |            | 1         | 0.2        |           |            |
| GOLDEN REDFISH      |           |            | 12        | 1.3        | 11        | 1.2        | 1         | <0.1       |
| LONGHORN SCULPIN    | 2         | 1.0        |           |            |           |            |           |            |
| SEA RAVEN           | 1         | 0.1        | 1         | 0.2        | 3         | 0.5        | 9         | 1.9        |
| ALLIGATOR FISH      | 4         | 3.0        |           |            | 1         | 0.5        | 4         | 2.5        |
| CUNNER              | 1         | <0.1       | 3         | <0.1       | 7         | <0.1       |           |            |
| SNAKEBLENY          |           |            |           |            | 1         | 0.2        | 9         | 0.6        |
| DAUBED SHANNY       |           |            | 63        | 2.7        | 112       | 3.8        | 2         | <0.1       |
| WRYMOUTH            |           |            | 4         | <0.1       | 18        | 0.2        | 6         | 0.1        |
| OCEAN POUT          |           |            | 1         | 1.6        |           |            |           |            |
| GOOSEFISH           | 16        | 6.3        | 7         | 0.7        | 10        | 4.0        | 17        | 4.6        |
| Total               | 563       | 93.2       | 1191      | 136.2      | 1883      | 177.7      | 734       | 128.9      |

Table II A-10

## ALL TRAWLS

## NFMS: Winter

|                     | N    | WT    | % N  | % WT |
|---------------------|------|-------|------|------|
| AMERICAN PLAICE     | 1253 | 137.5 | 66.3 | 45.4 |
| POLLOCK             | 158  | 9.6   | 8.4  | 3.2  |
| SILVER HAKE         | 113  | 2.4   | 6.0  | 0.8  |
| ATLANTIC HERRING    | 96   | 4.2   | 5.1  | 1.4  |
| WINTER FLOUNDER     | 92   | 38.6  | 4.9  | 12.8 |
| WITCH FLOUNDER      | 29   | 13.9  | 1.5  | 4.6  |
| LONGHORN SCULPIN    | 29   | 4.5   | 1.5  | 1.5  |
| HADDOCK             | 26   | 4.4   | 1.4  | 1.5  |
| REDFISH             | 20   | 10.0  | 1.1  | 3.3  |
| OCEAN POUT          | 19   | 16.6  | 1.0  | 5.5  |
| ATLANTIC COD        | 15   | 24.0  | 0.8  | 7.9  |
| ALEWIFE             | 11   | 14.0  | 0.6  | 4.6  |
| LITTLE SKATE        | 8    | 5.0   | 0.4  | 1.7  |
| RED HAKE            | 7    | 0.4   | 0.4  | 0.1  |
| SEA RAVEN           | 6    | 8.0   | 0.3  | 2.6  |
| YELLOWTAIL FLOUNDER | 6    | 2.1   | 0.3  | 0.7  |
| ATLANTIC WOLFFISH   | 1    | 7.2   | 0.1  | 2.4  |
| WHITE HAKE          | 1    | 0.2   | 0.1  | 0.1  |
| BLUEBACK HERRING    | 1    | 0.1   | 0.1  | <0.1 |
| Total:              | 1891 | 302.7 |      |      |

## NMFS: Summer

|                     | N   | WT   | % N  | % WT |
|---------------------|-----|------|------|------|
| AMERICAN PLAICE     | 280 | 36.5 | 80.2 | 32.0 |
| WITCH FLOUNDER      | 23  | 19.0 | 6.6  | 16.7 |
| RED HAKE            | 10  | 7.1  | 2.9  | 6.2  |
| THORNY SKATE        | 7   | 23.5 | 2.0  | 20.6 |
| ATLANTIC COD        | 7   | 8.4  | 2.0  | 7.4  |
| HADDOCK             | 5   | 1.3  | 1.4  | 1.1  |
| FOURSPOT FLOUNDER   | 4   | 4.5  | 1.1  | 3.9  |
| SPINY DOGFISH       | 3   | 9.9  | 0.9  | 8.7  |
| YELLOWTAIL FLOUNDER | 3   | 1.5  | 0.9  | 1.3  |
| SILVER HAKE         | 2   | 1.0  | 0.6  | 0.9  |
| OCEAN POUT          | 2   | 0.9  | 0.6  | 0.8  |
| WHITE HAKE          | 1   | 0.4  | 0.3  | 0.4  |
| GOLDEN REDFISH      | 1   | 0.1  | 0.3  | 0.1  |
| BUTTERFISH          | 1   | 0.1  | 0.3  | 0.1  |
| Total:              | 349 | 114  |      |      |

## ALL TRAWLS

## MDMF: Spring

|                     | N    | WT    | % N  | % WT |
|---------------------|------|-------|------|------|
| AMERICAN PLAICE     | 6584 | 581.2 | 80.7 | 58.7 |
| OCEAN POUT          | 402  | 195.3 | 4.9  | 19.7 |
| SNAKEBLENY          | 249  | 12.5  | 3.1  | 1.3  |
| DAUBED SHANNY       | 182  | 1.1   | 2.2  | 0.1  |
| SILVER HAKE         | 145  | 6.4   | 1.8  | 0.6  |
| ATLANTIC COD        | 110  | 58.5  | 1.3  | 5.9  |
| LONGHORN SCULPIN    | 100  | 10.7  | 1.2  | 1.1  |
| ATLANTIC HERRING    | 63   | 13.3  | 0.8  | 1.3  |
| RED HAKE            | 58   | 12.3  | 0.7  | 1.2  |
| WHITE HAKE          | 58   | 3.7   | 0.7  | 0.4  |
| ALEWIFE             | 36   | 13.8  | 0.4  | 1.4  |
| YELLOWTAIL FLOUNDER | 35   | 16.4  | 0.4  | 1.7  |
| FOURBEARD ROCKLING  | 29   | 1.6   | 0.4  | 0.2  |
| ALLIGATOR FISH      | 26   | 0.1   | 0.3  | 0.0  |
| WITCH FLOUNDER      | 26   | 38.8  | 0.3  | 3.9  |
| BLUEBACK HERRING    | 21   | 0.8   | 0.3  | 0.1  |
| WINTER FLOUNDER     | 16   | 3.8   | 0.2  | 0.4  |
| SEA RAVEN           | 10   | 11.3  | 0.1  | 1.1  |
| FOURSPOT FLOUNDER   | 4    | 0.5   | <0.1 | 0.1  |
| HADDOCK             | 3    | 2.1   | <0.1 | 0.2  |
| THORNY SKATE        | 3    | 3.5   | <0.1 | 0.4  |
| GOOSEFISH           | 1    | 0.1   | <0.1 | <0.1 |
| ATLANTIC WOLFFISH   | 1    | 2.5   | <0.1 | 0.3  |
| REDFISH             | 1    | 0.1   | <0.1 | <0.1 |
| Total:              | 8163 | 990   |      |      |

## NMFS: Spring

|                     | N    | WT    | % N  | % WT |
|---------------------|------|-------|------|------|
| AMERICAN PLAICE     | 822  | 161.5 | 66.6 | 41.5 |
| WITCH FLOUNDER      | 176  | 50.0  | 14.3 | 12.9 |
| AMERICAN SANDLANCE  | 62   | 0.2   | 5.0  | 0.1  |
| THORNY SKATE        | 31   | 34.6  | 2.5  | 8.9  |
| SILVER HAKE         | 28   | 1.9   | 2.3  | 0.5  |
| LONGHORN SCULPIN    | 26   | 4.9   | 2.1  | 1.3  |
| YELLOWTAIL FLOUNDER | 17   | 6.7   | 1.4  | 1.7  |
| ATLANTIC COD        | 15   | 78.7  | 1.2  | 20.2 |
| OCEAN POUT          | 15   | 9.8   | 1.2  | 2.5  |
| RED HAKE            | 13   | 2.5   | 1.1  | 0.6  |
| SEA RAVEN           | 12   | 6.9   | 1.0  | 1.8  |
| HADDOCK             | 8    | 4.6   | 0.6  | 1.2  |
| WINTER SKATE        | 3    | 15.3  | 0.2  | 3.9  |
| GOOSEFISH           | 2    | 10.2  | 0.2  | 2.6  |
| WINTER FLOUNDER     | 1    | 0.6   | 0.1  | 0.2  |
| FOURSPOT FLOUNDER   | 1    | 0.3   | 0.1  | 0.1  |
| ATLANTIC WOLFFISH   | 1    | <0.1  | 0.1  | 0.0  |
| POLLOCK             | 1    | <0.1  | 0.1  | 0.0  |
| Total:              | 1234 | 388.7 |      |      |

Table II A-12

## MEL. TRAWLS

## MDMF: Fall

|                     | N    | WT    | % N  | % WT |
|---------------------|------|-------|------|------|
| AMERICAN PLAICE     | 4053 | 297.0 | 58.9 | 32.4 |
| SILVER HAKE         | 1067 | 112.6 | 15.5 | 12.3 |
| RED HAKE            | 570  | 244.8 | 8.3  | 26.7 |
| ATLANTIC HERRING    | 334  | 20.9  | 4.9  | 2.3  |
| SNAKEBLENY          | 199  | 22.5  | 2.9  | 2.5  |
| WITCH FLOUNDER      | 138  | 69.0  | 2.0  | 7.5  |
| OCEAN POUT          | 130  | 46.2  | 1.9  | 5.0  |
| ATLANTIC COD        | 77   | 9.8   | 1.1  | 1.1  |
| WHITE HAKE          | 65   | 16.4  | 0.9  | 1.8  |
| ALEWIFE             | 57   | 2.9   | 0.8  | 0.3  |
| BUTTERFISH          | 34   | 2.7   | 0.5  | 0.3  |
| FOURBEARD ROCKLING  | 30   | 2.4   | 0.4  | 0.3  |
| DAUBED SHANNY       | 28   | 0.3   | 0.4  | 0.0  |
| LONGHORN SCULPIN    | 16   | 3.0   | 0.2  | 0.3  |
| SEA RAVEN           | 15   | 8.0   | 0.2  | 0.9  |
| ALLIGATOR FISH      | 12   | 0.0   | 0.2  | 0.0  |
| GOSEFISH            | 10   | 36.5  | 0.1  | 4.0  |
| CUNNER              | 10   | 0.8   | 0.1  | 0.1  |
| AMERICAN SHAD       | 9    | 1.2   | 0.1  | 0.1  |
| THORNY SKATE        | 9    | 7.8   | 0.1  | 0.9  |
| FOURSPOT FLOUNDER   | 4    | 2.1   | 0.1  | 0.2  |
| BLUEBACK HERRING    | 4    | 0.2   | 0.1  | 0.0  |
| WRYMOUTH            | 3    | 3.7   | 0.0  | 0.4  |
| YELLOWTAIL FLOUNDER | 3    | 1.9   | 0.0  | 0.2  |
| POLLOCK             | 3    | 0.9   | 0.0  | 0.1  |
| GOLDEN REDFISH      | 2    | 1.0   | 0.0  | 0.1  |
| HADDOCK             | 2    | 0.2   | 0.0  | 0.0  |
| WINDOWPANE          | 1    | 0.2   | 0.0  | 0.0  |
| WINTER FLOUNDER     | 1    | 0.9   | 0.0  | 0.1  |
| Total:              | 6886 | 916   |      |      |

## NMFS: Fall

|                     | N    | WT    | % N  | % WT |
|---------------------|------|-------|------|------|
| AMERICAN PLAICE     | 559  | 92.0  | 28.5 | 13.3 |
| ALEWIFE             | 459  | 100.5 | 23.4 | 14.5 |
| SILVER HAKE         | 356  | 45.4  | 18.1 | 6.6  |
| ATLANTIC COD        | 167  | 192.7 | 8.5  | 27.9 |
| GOLDEN REDFISH      | 99   | 32.6  | 5.0  | 4.7  |
| RED HAKE            | 85   | 48.0  | 4.3  | 6.9  |
| OCEAN POUT          | 50   | 23.4  | 2.5  | 3.4  |
| ATLANTIC WOLFFISH   | 32   | 10.0  | 1.6  | 1.4  |
| CUNNER              | 31   | 4.8   | 1.6  | 0.7  |
| WITCH FLOUNDER      | 26   | 20.6  | 1.3  | 3.0  |
| LONGHORN SCULPIN    | 17   | 15.3  | 0.9  | 2.2  |
| SEA RAVEN           | 17   | 12.8  | 0.9  | 1.9  |
| THORNY SKATE        | 11   | 43.8  | 0.6  | 6.3  |
| WHITE HAKE          | 8    | 3.1   | 0.4  | 0.4  |
| ATLANTIC HERRING    | 8    | 2.2   | 0.4  | 0.3  |
| POLLOCK             | 8    | 1.6   | 0.4  | 0.2  |
| BUTTERFISH          | 7    | 0.5   | 0.4  | 0.1  |
| WINTER FLOUNDER     | 6    | 2.3   | 0.3  | 0.3  |
| YELLOWTAIL FLOUNDER | 5    | 2.4   | 0.3  | 0.3  |
| HADDOCK             | 4    | 0.3   | 0.2  | 0.0  |
| GOSEFISH            | 3    | 33.5  | 0.2  | 4.8  |
| ATLANTIC MACKEREL   | 2    | 1.2   | 0.1  | 0.2  |
| SPINY DOGFISH       | 1    | 1.5   | 0.1  | 0.2  |
| CUSK                | 1    | 0.5   | 0.1  | 0.1  |
| SCUP                | 1    | 0.2   | 0.1  | 0.0  |
| Total:              | 1963 | 691.2 |      |      |

Table II A-13 Analysis of Variance comparing NMFS and MDMF spring and fall bottom trawls in the vicinity of MBDS.

Number of Fish Captured per Trawl

| <u>Source</u>  | <u>df</u> | <u>MS</u> | <u>F</u> | <u>P</u> |
|----------------|-----------|-----------|----------|----------|
| NMFS vs MDMF   | 1         | 2321632   | 10.6     | 0.04     |
| Spring vs Fall | 1         | 576487    | 2.6      | 0.10     |
| Interaction    | 1         | 280457    | 1.3      | ns       |
| Error          | 18        | 218116    |          |          |

Weight of Fish Captured per Trawl

| <u>Source</u>  | <u>df</u> | <u>MS</u> | <u>F</u> | <u>P</u> |
|----------------|-----------|-----------|----------|----------|
| NMFS vs MDMF   | 1         | 9         | <0.1     | ns       |
| Spring vs Fall | 1         | 4679      | 0.6      | ns       |
| Interaction    | 1         | 4227      | 0.6      | ns       |
| Error          | 18        | 7341      |          |          |

Number of Species Caught per Trawl

| <u>Source</u>  | <u>df</u> | <u>MS</u> | <u>F</u> | <u>P</u> |
|----------------|-----------|-----------|----------|----------|
| NMFS vs MDMF   | 1         | 19.64     | 1.6      | ns       |
| Spring vs Fall | 1         | 0.04      | <0.1     | ns       |
| Interaction    | 1         | 24.18     | 2.0      | ns       |
| Source         | 18        | 12.00     |          |          |



APPENDIX III

APPENDIX A  
Table III A-1  
VALUATION OF SPECIES  
1970-1974

|                 | YEAR<br>1970 | AREA<br>514 | LATITUDE<br>4225 | LONGITUDE<br>7025 |            |              |                |                |              |
|-----------------|--------------|-------------|------------------|-------------------|------------|--------------|----------------|----------------|--------------|
| SPECIES         | ROW1         | ROW2        | ROW1/ROW2        | ROW1'S VALUE      | LBS - ROW3 | NEW VALUE    | ROW3 LBS/VALUE | ELBS/VALUE*NEW |              |
| 081 (1972-7025) | 26,100       | 919,300     | 0.02839          | \$6,509,507.00    | 1,122,557  | 186,812.50   | 0.17245        | \$31,870.70    | VALUE/LBS/YR |
| 096             | 15,500       | 182,000     | 0.09956          | \$622,727.00      | 58,702     | 56,456.02    | 0.09627        | \$5,321.88     | VALUE/LBS/YR |
| 120             | 2,300        | 548,000     | 0.00420          | \$1,405,941.00    | 469,525    | 10,397.93    | 0.19515        | \$1,970.63     | VALUE/LBS/YR |
| 121             | 2,500        | 98,800      | 0.02530          | \$750,700.00      | 139,999    | 18,995.45    | 0.18669        | \$3,542.48     | VALUE/LBS/YR |
| 123             | 4,700        | 405,000     | 0.01160          | \$1,903,388.00    | 415,587    | 22,082.70    | 0.01834        | \$4,822.85     | VALUE/LBS/YR |
| 147             | 24,000       | 153,600     | 0.15625          | \$715,396.00      | 284,985    | 111,780.63   | 0.39836        | \$44,528.91    | VALUE/LBS/YR |
| 168             | 186,000      | 13,026,000  | 0.01423          | \$37,455,380.00   | 732,849    | 534,830.39   | 0.01957        | \$10,464.45    | VALUE/LBS/YR |
| 240             | 15,000       | 83,300      | 0.18037          | \$225,825.00      | 12,083     | 40,664.77    | 0.05351        | \$2,175.81     | VALUE/LBS/YR |
| 269             | 300          | 1,546,100   | 0.00019          | \$3,939,770.00    | 228,846    | 764.46       | 0.05809        | \$44.40        | VALUE/LBS/YR |
| 509             | 117,000      | 1,068,100   | 0.10954          | \$4,727,510.00    | 447,763    | 517,852.89   | 0.09471        | \$49,048.10    | VALUE/LBS/YR |
| 512             | 600          | 29,100      | 0.02062          | \$181,250.00      | 11,329     | 3,737.11     | 0.06250        | \$231.59       | VALUE/LBS/YR |
| 526             | 46,300       | 485,000     | 0.09546          | \$3,190,331.00    | 582,314    | 304,561.50   | 0.18252        | \$55,589.96    | VALUE/LBS/YR |
| 736             | 2,500        | 456,100     | 0.00548          | \$1,875,134.00    | 309,645    | 10,278.09    | 0.16513        | \$1,697.24     | VALUE/LBS/YR |
| 081 (7035)      | 26,500       | 919,300     | 0.02865          | \$6,509,507.00    | 1,122,557  | 173,483.00   | 0.17245        | \$29,915.94    | VALUE/LBS/YR |
| 096             | 200          | 182,000     | 0.00110          | \$622,727.00      | 58,702     | 684.32       | 0.09627        | \$54.51        | VALUE/LBS/YR |
| 120             | 2,400        | 548,000     | 0.00438          | \$1,405,941.00    | 469,525    | 10,536.97    | 0.19515        | \$2,056.31     | VALUE/LBS/YR |
| 121             | 300          | 98,800      | 0.00304          | \$750,700.00      | 193,999    | 2,379.45     | 0.25842        | \$589.07       | VALUE/LBS/YR |
| 123A            | 100          | 98,800      | 0.00101          | \$750,700.00      | 193,999    | 759.82       | 0.25842        | \$196.36       | VALUE/LBS/YR |
| 122             | 200          | 5,900       | 0.02390          | \$23,435.00       | 7,465      | 794.41       | 0.31654        | \$252.05       | VALUE/LBS/YR |
| 123             | 4,700        | 405,000     | 0.01160          | \$1,903,388.00    | 415,587    | 22,088.70    | 0.01834        | \$4,822.86     | VALUE/LBS/YR |
| 147             | 160          | 153,000     | 0.00105          | \$715,396.00      | 284,985    | 768.13       | 0.39836        | \$298.02       | VALUE/LBS/YR |
| 168             | 40,000       | 13,026,000  | 0.00307          | \$37,455,380.00   | 732,849    | 115,017.29   | 0.01957        | \$2,250.42     | VALUE/LBS/YR |
| 240             | 2,800        | 83,300      | 0.03361          | \$225,825.00      | 12,083     | 7,590.76     | 0.05351        | \$436.15       | VALUE/LBS/YR |
| 269             | 9,500        | 1,546,100   | 0.00621          | \$3,939,770.00    | 228,846    | 24,462.71    | 0.05809        | \$1,420.94     | VALUE/LBS/YR |
| 509             | 21,200       | 1,068,100   | 0.01985          | \$4,727,510.00    | 447,763    | 93,833.17    | 0.09471        | \$8,887.35     | VALUE/LBS/YR |
| 512             | 1,800        | 29,100      | 0.06186          | \$181,250.00      | 11,329     | 11,211.34    | 0.06250        | \$700.76       | VALUE/LBS/YR |
| 526             | 2,300        | 485,000     | 0.00474          | \$3,190,331.00    | 582,314    | 15,129.40    | 0.18252        | \$2,761.49     | VALUE/LBS/YR |
| 081 (7045)      | 26,500       | 919,300     | 0.02894          | \$6,509,507.00    | 1,122,557  | 188,352.97   | 0.17245        | \$32,481.25    | VALUE/LBS/YR |
| 120             | 23,100       | 548,000     | 0.04252          | \$1,405,941.00    | 469,525    | 102,296.40   | 0.19515        | \$19,963.38    | VALUE/LBS/YR |
| 123             | 37,000       | 405,000     | 0.09136          | \$1,903,388.00    | 415,587    | 173,889.77   | 0.01834        | \$37,967.21    | VALUE/LBS/YR |
| 147             | 1,400        | 153,600     | 0.00911          | \$715,396.00      | 284,985    | 6,520.54     | 0.39836        | \$2,597.52     | VALUE/LBS/YR |
| 168             | 125,000      | 13,026,000  | 0.00960          | \$37,455,380.00   | 732,849    | 359,429.03   | 0.01957        | \$7,032.56     | VALUE/LBS/YR |
| 509             | 33,000       | 1,068,100   | 0.03090          | \$4,727,510.00    | 447,763    | 146,051.07   | 0.09471        | \$13,834.08    | VALUE/LBS/YR |
| 512             | 100          | 29,100      | 0.00344          | \$181,250.00      | 11,329     | 622.85       | 0.06250        | \$38.93        | VALUE/LBS/YR |
| 526             | 18,800       | 485,000     | 0.03876          | \$3,190,331.00    | 582,314    | 123,666.44   | 0.18252        | \$22,572.17    | VALUE/LBS/YR |
| 736             | 200          | 456,100     | 0.00244          | \$1,875,134.00    | 309,645    | 822.25       | 0.16513        | \$135.78       | VALUE/LBS/YR |
| 081 (1973-7025) | 26,600       | 735,200     | 0.03618          | \$5,368,576.00    | 838,521    | 194,238.47   | 0.15619        | \$30,338.22    | VALUE/LBS/YR |
| 096             | 15,700       | 137,200     | 0.11443          | \$680,401.00      | 77,573     | 77,859.30    | 0.11401        | \$8,876.79     | VALUE/LBS/YR |
| 120             | 2,300        | 554,000     | 0.00415          | \$193,582.00      | 32,676     | 803.68       | 0.16880        | \$135.66       | VALUE/LBS/YR |
| 122             | 1,700        | 554,100     | 0.00307          | \$193,582.00      | 32,676     | 593.92       | 0.16880        | \$100.25       | VALUE/LBS/YR |
| 123             | 7,300        | 543,000     | 0.01344          | \$135,302.00      | 26,875     | 1,818.98     | 0.19863        | \$361.30       | VALUE/LBS/YR |
| 124             | 4,800        | 73,500      | 0.06531          | \$886,082.00      | 141,819    | 57,866.97    | 0.16035        | \$9,261.65     | VALUE/LBS/YR |
| 147             | 11,600       | 85,800      | 0.13520          | \$415,293.00      | 177,596    | 56,146.84    | 0.42764        | \$24,010.65    | VALUE/LBS/YR |
| 153             | 5,400        | 18,400      | 0.29348          | \$2,223,669.00    | 168,161    | 652,592.51   | 0.07562        | \$49,351.60    | VALUE/LBS/YR |
| 269             | 1,300        | 1,222,900   | 0.00106          | \$2,445,777.00    | 206,628    | 2,599.98     | 0.08448        | \$219.66       | VALUE/LBS/YR |
| 509             | 369,000      | 2,495,000   | 0.14790          | \$19,743,596.00   | 638,793    | 1,588,932.63 | 0.05946        | \$94,474.80    | VALUE/LBS/YR |
| 512             | 1,400        | 13,000      | 0.10769          | \$54,335.00       | 3,546      | 5,851.46     | 0.05526        | \$381.88       | VALUE/LBS/YR |

|                 |         |           |         |                 |           |              |         |              |              |
|-----------------|---------|-----------|---------|-----------------|-----------|--------------|---------|--------------|--------------|
| 72              | 40,700  | 500,400   | 0.04839 | \$1,688,358.00  | 248,930   | 81,700.91    | 0.14744 | \$12,045.91  | VALUE/LBS/YR |
| 73              | 77,600  | 441,400   | 0.17501 | \$15,556,158.00 | 4,241,985 | 2,726,048.62 | 0.17357 | \$745,759.03 | VALUE/LBS/YR |
| 602             | 59,100  | 559,400   | 0.11724 | \$647,291.00    | 153,009   | 75,807.02    | 0.13638 | \$17,938.45  | VALUE/LBS/YR |
| 081 (7035)      | 2,000   | 735,000   | 0.00209 | \$5,368,576.00  | 835,521   | 26,069.21    | 0.15519 | \$2,509.86   | VALUE/LBS/YR |
| 120             | 500     | 554,100   | 0.00108 | \$193,582.00    | 32,676    | 6,069.62     | 0.16820 | \$35.36      | VALUE/LBS/YR |
| 123             | 5,700   | 543,800   | 0.01048 | \$135,302.00    | 26,875    | 1,418.21     | 0.19563 | \$281.70     | VALUE/LBS/YR |
| 158             | 145,000 | 5,532,000 | 0.02501 | \$11,533,135.00 | 364,225   | 302,296.56   | 0.03158 | \$9,546.75   | VALUE/LBS/YR |
| 509             | 596,500 | 2,495,500 | 0.23921 | \$10,743,596.00 | 638,793   | 2,568,044.49 | 0.05946 | \$152,690.85 | VALUE/LBS/YR |
| 526             | 34,900  | 882,400   | 0.03955 | \$1,688,358.00  | 348,930   | 66,776.63    | 0.20567 | \$19,800.61  | VALUE/LBS/YR |
| 736             | 34,400  | 441,400   | 0.07793 | \$15,506,168.00 | 4,241,985 | 1,208,455.32 | 0.27357 | \$330,594.21 | VALUE/LBS/YR |
| 081 (7045)      | 27,500  | 735,000   | 0.03755 | \$5,368,576.00  | 838,521   | 201,595.51   | 0.15619 | \$31,457.32  | VALUE/LBS/YR |
| 120             | 19,600  | 554,100   | 0.03537 | \$193,582.00    | 32,676    | 6,847.51     | 0.16880 | \$1,155.84   | VALUE/LBS/YR |
| 123             | 27,400  | 543,800   | 0.05039 | \$135,302.00    | 26,875    | 6,817.35     | 0.19863 | \$1,354.13   | VALUE/LBS/YR |
| 124             | 100     | 73,500    | 0.00136 | \$825,088.00    | 141,819   | 1,205.56     | 0.16005 | \$192.95     | VALUE/LBS/YR |
| 147             | 300     | 85,800    | 0.00350 | \$419,293.00    | 177,569   | 1,466.06     | 0.40350 | \$620.87     | VALUE/LBS/YR |
| 153             | 500     | 18,400    | 0.02717 | \$2,223,669.00  | 168,161   | 69,425.79    | 0.07562 | \$4,569.59   | VALUE/LBS/YR |
| 168             | 50,000  | 5,532,000 | 0.00904 | \$11,533,135.00 | 364,225   | 104,240.19   | 0.03158 | \$3,291.98   | VALUE/LBS/YR |
| 269             | 100     | 1,222,900 | 0.00008 | \$2,445,777.00  | 206,628   | 200.00       | 0.08448 | \$15.90      | VALUE/LBS/YR |
| 526             | 3,000   | 882,400   | 0.00340 | \$1,688,358.00  | 348,930   | 5,740.11     | 0.20667 | \$1,186.30   | VALUE/LBS/YR |
| 081 (1974-7025) | 4,000   | 574,000   | 0.00732 | \$6,752,990.00  | 1,281,369 | 49,412.12    | 0.18975 | \$9,375.87   | VALUE/LBS/YR |
| 096             | 3,900   | 102,500   | 0.03005 | \$1,117,005.00  | 162,501   | 42,500.68    | 0.14548 | \$6,182.96   | VALUE/LBS/YR |
| 121             | 500     | 26,200    | 0.01908 | \$469,422.00    | 181,188   | 8,958.44     | 0.38598 | \$3,457.79   | VALUE/LBS/YR |
| 123             | 11,400  | 373,200   | 0.03055 | \$2,594,579.00  | 674,698   | 79,255.63    | 0.26004 | \$20,609.75  | VALUE/LBS/YR |
| 147             | 600     | 52,300    | 0.00961 | \$448,329.00    | 198,946   | 4,317.78     | 0.44375 | \$1,916.01   | VALUE/LBS/YR |
| 153             | 2,300   | 48,000    | 0.04792 | \$1,213,245.00  | 124,001   | 58,134.66    | 0.10221 | \$5,841.71   | VALUE/LBS/YR |
| 168             | 85,000  | 6,973,600 | 0.01219 | \$10,753,330.00 | 349,135   | 131,292.36   | 0.03244 | \$4,255.55   | VALUE/LBS/YR |
| 509             | 167,400 | 1,590,400 | 0.10526 | \$5,806,049.00  | 504,473   | 611,124.62   | 0.08689 | \$53,089.08  | VALUE/LBS/YR |
| 512             | 2,300   | 42,600    | 0.03052 | \$287,996.00    | 17,641    | 8,782.61     | 0.06125 | \$538.34     | VALUE/LBS/YR |
| 526             | 85,800  | 1,417,500 | 0.06053 | \$4,742,103.00  | 821,902   | 286,974.70   | 0.17336 | \$49,748.99  | VALUE/LBS/YR |
| 736             | 41,000  | 441,000   | 0.09297 | \$2,155,585.00  | 561,371   | 200,405.86   | 0.26043 | \$52,190.95  | VALUE/LBS/YR |
| 081 (7035)      | 10,800  | 574,000   | 0.01879 | \$6,752,990.00  | 1,281,369 | 126,882.90   | 0.18975 | \$24,075.83  | VALUE/LBS/YR |
| 120             | 5,200   | 219,700   | 0.02367 | \$1,664,082.00  | 380,992   | 39,386.56    | 0.22895 | \$9,017.56   | VALUE/LBS/YR |
| 123             | 5,900   | 373,200   | 0.01581 | \$2,594,579.00  | 674,698   | 41,018.26    | 0.26004 | \$10,666.45  | VALUE/LBS/YR |
| 509             | 30,000  | 1,590,400 | 0.01886 | \$5,806,049.00  | 504,473   | 109,520.54   | 0.08589 | \$9,515.96   | VALUE/LBS/YR |
| 512             | 100     | 42,600    | 0.00235 | \$287,996.00    | 17,641    | 676.05       | 0.06125 | \$41.41      | VALUE/LBS/YR |
| 526             | 78,600  | 1,417,000 | 0.05547 | \$4,742,103.00  | 821,902   | 262,985.67   | 0.17336 | \$45,595.13  | VALUE/LBS/YR |
| 736             | 4,500   | 441,000   | 0.01020 | \$2,155,585.00  | 561,371   | 21,995.77    | 0.26043 | \$5,728.28   | VALUE/LBS/YR |
| 081 (7045)      | 11,200  | 574,800   | 0.01949 | \$6,752,990.00  | 1,281,369 | 131,582.27   | 0.18975 | \$24,957.52  | VALUE/LBS/YR |
| 120             | 7,700   | 219,700   | 0.03505 | \$1,664,082.00  | 380,992   | 58,322.40    | 0.22895 | \$13,352.93  | VALUE/LBS/YR |
| 123             | 10,800  | 373,200   | 0.02894 | \$2,594,579.00  | 674,698   | 75,084.28    | 0.26004 | \$19,525.02  | VALUE/LBS/YR |
| 512             | 200     | 42,600    | 0.00469 | \$287,996.00    | 17,641    | 1,352.09     | 0.06125 | \$82.82      | VALUE/LBS/YR |

#### YEARLY TOTALS

|              |            |             |                |                |
|--------------|------------|-------------|----------------|----------------|
| 1972 ALL-LBS | 13,954,741 | 1972 ALL-\$ | \$402,558.16   | TOTAL VALUE-72 |
| 1973 ALL-LBS | 15,786,197 | 1973 ALL-\$ | \$1,545,591.08 | TOTAL VALUE-73 |
| 1974 ALL-LBS | 11,474,371 | 1974 ALL-\$ | \$369,881.12   | TOTAL VALUE-74 |

#### TEN MIN TOTALS

| YEAR | LATITUDE | LONGITUDE |              |                              |
|------|----------|-----------|--------------|------------------------------|
| 1972 | 4225     | 7025      | 4,816,184.00 | \$211,311.04 TOTAL-\$/10 MIN |
|      | 4225     | 7035      | 4,762,003.00 | \$54,624.24 TOTAL-\$/10 MIN  |
|      | 4225     | 7045      | 4,376,554.00 | \$136,622.88 TOTAL-\$/10 MIN |

|      |      |      |              |                              |
|------|------|------|--------------|------------------------------|
| 1973 | 4225 | 7025 | 6,966,788.00 | \$923,355.84 TOTAL-\$ 10 MIN |
|      | 4225 | 7035 | 6,492,005.00 | \$509,459.36 TOTAL-\$100 MIN |
|      | 4225 | 7045 | 2,355,404.00 | \$43,875.82 TOTAL-\$ 10 MIN  |
| 1974 | 4225 | 7025 | 4,877,225.00 | \$207,317.01 TOTAL-\$100 MIN |
|      | 4225 | 7035 | 4,242,446.00 | \$104,635.82 TOTAL-\$100 MIN |
|      | 4225 | 7045 | 2,354,700.00 | \$57,926.30 TOTAL-\$100 MIN  |

APPENDIX I  
Table III A-2  
VALUATION OF SPECIES  
1961 - 1964

| SPECIES         | LATITUDE  | LONGITUDE  | AREA | ROW1/ROW2 | ROW3(\$)        | VALUE | LBS - ROW1 | NEW VALUE    | ROW1 LBS/VALUE | ROW3 LBS/VALUE*NEW          |
|-----------------|-----------|------------|------|-----------|-----------------|-------|------------|--------------|----------------|-----------------------------|
| 023 (1961-7006) | 1.334     | 2.315      | 514  | 0.57624   | \$3,854,544.00  |       | 2,103,718  | 2,226,912.18 | 0.54436        | \$1,212,259.46 VALUE/LBS/YR |
| 051             | 319       | 30.803     | 514  | 0.01035   | \$76,812.00     |       | 29.385     | 795.48       | 0.38256        | \$304.32 VALUE/LBS/YR       |
| 081             | 831.784   | 4.087.034  | 514  | 0.20352   | \$13,398,573.00 |       | 4,580.839  | 2,725,847.55 | 0.34189        | \$932,282.09 VALUE/LBS/YR   |
| 096             | 3.147     | 62.085     | 514  | 0.05069   | \$275,994.00    |       | 53.224     | 13,929.74    | 0.19284        | \$2,697.85 VALUE/LBS/YR     |
| 120             | 41.909    | 480.541    | 514  | 0.08578   | \$2,830,162.00  |       | 621.986    | 328,565.61   | 0.16279        | \$53,355.45 VALUE/LBS/YR    |
| 122             | 9.283     | 111.970    | 514  | 0.03291   | \$941,149.00    |       | 621.986    | 78,027.03    | 0.66088        | \$51,566.45 VALUE/LBS/YR    |
| 123             | 51.855    | 355.812    | 514  | 0.14574   | \$3,854,544.00  |       | 2,103,718  | 563,207.34   | 0.54436        | \$305,589.71 VALUE/LBS/YR   |
| 124             | 30.540    | 505.839    | 514  | 0.06026   | \$5,615,917.00  |       | 2,592,627  | 338,391.69   | 0.46166        | \$156,210.87 VALUE/LBS/YR   |
| 125             | 105       | 20.560     | 514  | 0.03511   | \$185,652.00    |       | 27.210     | 953.28       | 0.14577        | \$138.95 VALUE/LBS/YR       |
| 126             | 2.355     | 14.740     | 514  | 0.15977   | \$66,613.00     |       | 31.463     | 10,641.71    | 0.67233        | \$5,026.82 VALUE/LBS/YR     |
| 147             | 7.731     | 738.363    | 514  | 0.01047   | \$1,393,004.00  |       | 752.778    | 14,585.39    | 0.54040        | \$7,881.93 VALUE/LBS/YR     |
| 152             | 14.180    | 117.390    | 514  | 0.10079   | \$185,662.00    |       | 27.210     | 22,547.64    | 0.14577        | \$3,286.60 VALUE/LBS/YR     |
| 153             | 2.344     | 101.529    | 514  | 0.02309   | \$630,942.00    |       | 127.303    | 14,566.56    | 0.20177        | \$2,919.64 VALUE/LBS/YR     |
| 159             | 44        | 1.945      | 514  | 0.02261   | \$15,072.00     |       | 17.111     | 340.79       | 1.12528        | \$385.89 VALUE/LBS/YR       |
| 168             | 1.885     | 4.664.978  | 514  | 0.00040   | \$11,051,013.00 |       | 497.554    | 4,455.44     | 0.04552        | \$201.05 VALUE/LBS/YR       |
| 212             | 2.215     | 12.205     | 514  | 0.18148   | \$392,789.00    |       | 98.828     | 71,284.53    | 0.25161        | \$17,935.60 VALUE/LBS/YR    |
| 240             | 15.200    | 230.325    | 514  | 0.07034   | \$395,802.00    |       | 104.149    | 27,205.87    | 0.26926        | \$7,325.36 VALUE/LBS/YR     |
| 259             | 38.575    | 1,350.652  | 514  | 0.02655   | \$3,355,303.00  |       | 648.022    | 95,830.88    | 0.19313        | \$18,508.17 VALUE/LBS/YR    |
| 350             | 1.060     | 1.060      | 514  | 1.00000   | \$308,110.00    |       | 20.038     | 308,110.00   | 0.05504        | \$20,038.00 VALUE/LBS/YR    |
| 352             | 1.141.654 | 2.310.292  | 514  | 0.49415   | \$6,028,056.00  |       | 396.748    | 2,978,855.45 | 0.06582        | \$196,058.73 VALUE/LBS/YR   |
| 355             | 2.258     | 19.137     | 514  | 0.12851   | \$235,376.00    |       | 23.397     | 27,895.32    | 0.09940        | \$2,772.87 VALUE/LBS/YR     |
| 509             | 52.438    | 397.384    | 514  | 0.15712   | \$4,953,697.00  |       | 991.771    | 779,908.89   | 0.19980        | \$155,829.62 VALUE/LBS/YR   |
| 512             | 7.362     | 74.544     | 514  | 0.09875   | \$399,513.00    |       | 77.597     | 39,455.09    | 0.19423        | \$7,653.52 VALUE/LBS/YR     |
| 526             | 4.575     | 43.336     | 514  | 0.10788   | \$595,489.00    |       | 239.492    | 64,348.03    | 0.40150        | \$25,835.91 VALUE/LBS/YR    |
| 529             | 2.400     | 7.350      | 514  | 0.32653   | \$128,635.00    |       | 10.916     | 42,003.27    | 0.08485        | \$3,554.41 VALUE/LBS/YR     |
| 736             | 2.165     | 113.305    | 514  | 0.01911   | \$2,190,790.00  |       | 1,407,129  | 41,861.00    | 0.54229        | \$26,867.02 VALUE/LBS/YR    |
| 802             | 1.800     | 385        | 514  | 4.67532   | \$2,610.00      |       | 453        | 12,202.60    | 0.17255        | \$2,117.92 VALUE/LBS/YR     |
| 012 (7035)      | 151       | 44.984     | 514  | 0.00335   | \$522,068.00    |       | 302.467    | 1,752.45     | 0.57936        | \$1,015.31 VALUE/LBS/YR     |
| 081             | 78.418    | 4.087.034  | 514  | 0.01919   | \$13,398,573.00 |       | 4,580.839  | 257,078.68   | 0.34189        | \$87,892.65 VALUE/LBS/YR    |
| 096             | 113       | 62.085     | 514  | 0.00182   | \$275,994.00    |       | 53.224     | 502.33       | 0.19284        | \$96.87 VALUE/LBS/YR        |
| 120             | 11.450    | 488.541    | 514  | 0.02344   | \$3,830,162.00  |       | 1,601,279  | 89,768.01    | 0.41807        | \$37,529.39 VALUE/LBS/YR    |
| 122             | 4.395     | 111.970    | 514  | 0.03925   | \$941,149.00    |       | 621.986    | 36,941.59    | 0.66088        | \$24,423.94 VALUE/LBS/YR    |
| 123             | 7.455     | 355.812    | 514  | 0.02395   | \$3,854,544.00  |       | 2,103,718  | 80,970.22    | 0.54436        | \$44,077.26 VALUE/LBS/YR    |
| 124             | 2.523     | 509.839    | 514  | 0.00495   | \$5,615,917.00  |       | 2,592,627  | 27,791.04    | 0.46166        | \$12,829.93 VALUE/LBS/YR    |
| 125             | 1.240     | 14.740     | 514  | 0.08412   | \$66,613.00     |       | 31.463     | 5,603.81     | 0.47233        | \$2,545.82 VALUE/LBS/YR     |
| 147             | 570       | 738.363    | 514  | 0.09077   | \$1,393,004.00  |       | 752.778    | 1,075.37     | 0.54040        | \$581.13 VALUE/LBS/YR       |
| 221             | 2.264.960 | 19,116.980 | 514  | 0.11848   | \$21,304,180.00 |       | 439.688    | 2,524,097.19 | 0.02064        | \$52,053.78 VALUE/LBS/YR    |
| 240             | 450       | 230.325    | 514  | 0.00195   | \$386,802.00    |       | 104.149    | 755.72       | 0.26926        | \$203.43 VALUE/LBS/YR       |
| 259             | 7.051     | 1,350.653  | 514  | 0.05522   | \$3,355,303.00  |       | 648.022    | 17,516.15    | 0.19313        | \$3,382.96 VALUE/LBS/YR     |
| 512             | 2.730     | 74.544     | 514  | 0.03662   | \$399,513.00    |       | 77.597     | 14,631.23    | 0.19423        | \$2,841.81 VALUE/LBS/YR     |
| 012 (1981-7026) | 5.015     | 74.847     | 514  | 0.08035   | \$454,681.00    |       | 253.303    | 37,343.60    | 0.56563        | \$21,160.07 VALUE/LBS/YR    |
| 023             | 1.658     | 18.018     | 514  | 0.09202   | \$255,335.00    |       | 36.873     | 23,495.69    | 0.14441        | \$3,393.02 VALUE/LBS/YR     |
| 051             | 145       | 6.645      | 514  | 0.02182   | \$54,244.00     |       | 26.424     | 1,401.85     | 0.41131        | \$576.50 VALUE/LBS/YR       |
| 081             | 1,197.210 | 4,805.270  | 514  | 0.24909   | \$14,124,290.00 |       | 4,942.422  | 3,518,267.02 | 0.34992        | \$1,231,122.07 VALUE/LBS/YR |
| 096             | 4.372     | 90.355     | 514  | 0.04839   | \$388,732.00    |       | 51.126     | 9,132.16     | 0.27589        | \$2,473.83 VALUE/LBS/YR     |
| 120             | 30.215    | 407.291    | 514  | 0.07419   | \$2,936,176.00  |       | 299.410    | 217,821.05   | 0.44255        | \$96,397.10 VALUE/LBS/YR    |
| 122             | 90        | 4.825      | 514  | 0.01855   | \$30,506.00     |       | 41.951     | 569.02       | 1.13762        | \$701.10 VALUE/LBS/YR       |

|            |           |            |         |                 |           |              |         |              |              |
|------------|-----------|------------|---------|-----------------|-----------|--------------|---------|--------------|--------------|
| 122        | 22.570    | 236.465    | 0.00545 | \$1,055,740.00  | 687.120   | 100,767.77   | 0.65084 | \$65,581.91  | VALUE/LBS/YR |
| 123        | 50.171    | 349.687    | 0.14347 | \$2,183,859.00  | 1,150.445 | 323,327.03   | 0.52679 | \$165,058.97 | VALUE/LBS/YR |
| 124        | 55.849    | 651.837    | 0.08571 | \$4,570,713.00  | 2,151.215 | 391,756.17   | 0.47065 | \$184,380.81 | VALUE/LBS/YR |
| 125        | 40        | 19,060     | 0.00210 | \$117,154.00    | 17.480    | 245.86       | 0.14901 | \$36.68      | VALUE/LBS/YR |
| 126        | 7.455     | 14,950     | 0.49933 | \$31,346.00     | 12.413    | 15,652.03    | 0.39600 | \$6,198.10   | VALUE/LBS/YR |
| 147        | 49.361    | 771.927    | 0.06395 | \$1,652,761.00  | 1,025,661 | 105,688.22   | 0.62057 | \$65,587.39  | VALUE/LBS/YR |
| 152        | 5.780     | 163,590    | 0.01533 | \$1,551,445.00  | 135,379   | 54,816.02    | 0.08726 | \$4,783.24   | VALUE/LBS/YR |
| 153        | 7.461     | 126,834    | 0.05082 | \$583,600.00    | 106,550   | 34,330.22    | 0.18257 | \$6,267.80   | VALUE/LBS/YR |
| 159        | 274       | 3,394      | 0.00073 | \$9,246.00      | 9,418     | 745.44       | 1.01850 | \$760.32     | VALUE/LBS/YR |
| 168        | 70        | 2,153,077  | 0.00003 | \$5,658,106.00  | 260,090   | 183.95       | 0.04597 | \$8.45       | VALUE/LBS/YR |
| 212        | 15.635    | 66,941     | 0.25189 | \$876,670.00    | 236,978   | 220,823.51   | 0.27032 | \$59,692.15  | VALUE/LBS/YR |
| 240        | 18.070    | 244,049    | 0.07404 | \$349,503.00    | 82,274    | 25,878.08    | 0.23540 | \$5,091.77   | VALUE/LBS/YR |
| 250        | 1.609     | 90,790     | 0.01762 | \$694,397.00    | 51,556    | 12,237.42    | 0.07425 | \$908.58     | VALUE/LBS/YR |
| 269        | 92,016    | 1,028,577  | 0.09042 | \$3,140,250.00  | 525,766   | 283,978.25   | 0.16743 | \$47,545.93  | VALUE/LBS/YR |
| 347        | 10        | 25         | 0.40000 | \$5,797.00      | 557       | 2,318.80     | 0.09608 | \$222.80     | VALUE/LBS/YR |
| 352        | 1,696,000 | 5,391,755  | 0.29786 | \$9,985,350.00  | 630,301   | 2,974,555.17 | 0.06312 | \$187,742.84 | VALUE/LBS/YR |
| 365        | 3,474     | 51,235     | 0.06781 | \$454,931.00    | 27,083    | 30,846.69    | 0.05953 | \$1,836.37   | VALUE/LBS/YR |
| 509        | 272,145   | 1,507,812  | 0.18049 | \$7,499,013.00  | 951,649   | 1,353,496.92 | 0.12690 | \$171,763.14 | VALUE/LBS/YR |
| 512        | 27,324    | 202,555    | 0.13490 | \$691,178.00    | 131,262   | 93,237.63    | 0.18991 | \$17,706.81  | VALUE/LBS/YR |
| 526        | 9,540     | 105,875    | 0.09011 | \$778,185.00    | 182,941   | 70,119.34    | 0.23509 | \$16,484.13  | VALUE/LBS/YR |
| 736        | 19,745    | 59,375     | 0.33255 | \$597,870.00    | 303,259   | 198,820.10   | 0.50723 | \$100,847.95 | VALUE/LBS/YR |
| 812 (7035) | 1,870     | 74,849     | 0.02498 | \$464,681.00    | 263,303   | 11,609.42    | 0.56663 | \$6,578.27   | VALUE/LBS/YR |
| 823        | 44        | 18,018     | 0.00244 | \$255,335.00    | 36,873    | 623.53       | 0.14441 | \$90.04      | VALUE/LBS/YR |
| 851        | 100       | 6,645      | 0.01505 | \$64,244.00     | 25,424    | 955.80       | 0.41131 | \$397.65     | VALUE/LBS/YR |
| 881        | 174,828   | 4,806,270  | 0.03721 | \$14,124,290.00 | 4,942,412 | 525,525.73   | 0.34992 | \$183,893.47 | VALUE/LBS/YR |
| 896        | 334       | 90,355     | 0.00370 | \$188,732.00    | 51,126    | 697.65       | 0.27089 | \$188.99     | VALUE/LBS/YR |
| 120        | 13,890    | 407,291    | 0.03410 | \$2,936,176.00  | 1,299,410 | 100,133.53   | 0.44255 | \$44,314.27  | VALUE/LBS/YR |
| 121        | 285       | 4,825      | 0.05907 | \$41,983.00     | 30,506    | 2,479.82     | 0.72663 | \$1,801.92   | VALUE/LBS/YR |
| 122        | 5,161     | 236,465    | 0.02183 | \$1,055,740.00  | 687.120   | 23,042.20    | 0.65084 | \$14,996.83  | VALUE/LBS/YR |
| 123        | 21,255    | 349,687    | 0.06078 | \$2,183,859.00  | 1,150,445 | 132,741.35   | 0.52679 | \$59,927.42  | VALUE/LBS/YR |
| 124        | 20,295    | 651.837    | 0.03214 | \$4,570,713.00  | 2,151,215 | 142,309.53   | 0.47065 | \$65,978.26  | VALUE/LBS/YR |
| 126        | 150       | 14,950     | 0.01093 | \$31,346.00     | 12.413    | 314.51       | 0.39600 | \$124.55     | VALUE/LBS/YR |
| 147        | 1,557     | 771.927    | 0.00202 | \$1,652,761.00  | 1,025,661 | 3,333.67     | 0.62057 | \$1,968.79   | VALUE/LBS/YR |
| 152        | 4.455     | 163,590    | 0.02723 | \$1,551,445.00  | 135,379   | 42,250.06    | 0.08726 | \$3,686.74   | VALUE/LBS/YR |
| 153        | 268       | 126,834    | 0.00211 | \$583,600.00    | 106,550   | 1,233.15     | 0.18257 | \$225.14     | VALUE/LBS/YR |
| 168        | 699,740   | 2,153,077  | 0.32500 | \$5,658,150.00  | 260,090   | 1,838,872.40 | 0.04597 | \$84,528.04  | VALUE/LBS/YR |
| 221        | 277,440   | 32,423,150 | 0.00856 | \$44,723,515.00 | 777,364   | 382,692.37   | 0.01738 | \$6,651.79   | VALUE/LBS/YR |
| 240        | 1,610     | 244,099    | 0.00660 | \$349,503.00    | 82,274    | 2,305.21     | 0.23540 | \$542.65     | VALUE/LBS/YR |
| 269        | 7,307     | 1,029,577  | 0.00710 | \$3,140,250.00  | 525,766   | 22,308.30    | 0.16743 | \$3,735.04   | VALUE/LBS/YR |
| 352        | 8,000     | 5,391,755  | 0.00148 | \$9,986,350.00  | 630,301   | 14,817.22    | 0.06312 | \$935.21     | VALUE/LBS/YR |
| 365        | 976       | 51,235     | 0.01905 | \$454,931.00    | 27,083    | 8,666.20     | 0.05953 | \$515.92     | VALUE/LBS/YR |
| 509        | 4,190     | 1,507,812  | 0.00278 | \$7,499,013.00  | 951,649   | 20,838.71    | 0.12690 | \$2,644.50   | VALUE/LBS/YR |
| 512        | 8,904     | 202,555    | 0.04396 | \$691,178.00    | 131,262   | 30,383.10    | 0.18991 | \$5,770.07   | VALUE/LBS/YR |
| 526        | 1,575     | 105,875    | 0.01488 | \$778,185.00    | 182,941   | 11,576.31    | 0.23509 | \$2,721.44   | VALUE/LBS/YR |
| 736        | 7,130     | 59,375     | 0.12008 | \$597,870.00    | 303,259   | 71,794.75    | 0.50723 | \$36,416.62  | VALUE/LBS/YR |
| 812 (7045) | 110       | 74,847     | 0.00147 | \$464,681.00    | 263,303   | 682.93       | 0.56663 | \$386.97     | VALUE/LBS/YR |
| 881        | 7,786     | 4,806,270  | 0.00162 | \$14,124,290.00 | 4,942,412 | 22,880.89    | 0.34992 | \$8,006.55   | VALUE/LBS/YR |
| 896        | 73        | 90,355     | 0.00081 | \$51,126.00     | 188,732   | 41.31        | 3.69151 | \$152.48     | VALUE/LBS/YR |
| 120        | 3,960     | 407,291    | 0.00972 | \$2,936,176.00  | 1,299,410 | 28,547.79    | 0.44255 | \$12,633.88  | VALUE/LBS/YR |
| 122        | 1,235     | 236,465    | 0.00522 | \$1,055,740.00  | 687.120   | 5,513.88     | 0.65084 | \$3,588.66   | VALUE/LBS/YR |
| 123        | 1,665     | 349,687    | 0.00476 | \$2,183,859.00  | 1,150,445 | 10,398.23    | 0.52679 | \$5,477.73   | VALUE/LBS/YR |
| 124        | 3,590     | 651,837    | 0.00551 | \$4,570,713.00  | 2,151,215 | 25,173.26    | 0.47065 | \$11,847.84  | VALUE/LBS/YR |
| 168        | 112,740   | 2,153,077  | 0.05236 | \$0.00          | 0         | 0.00         | ERR     | \$0.00       | VALUE/LBS/YR |
| 212        | 595       | 66,941     | 0.00901 | \$876,670.00    | 236,978   | 7,898.41     | 0.27032 | \$2,135.07   | VALUE/LBS/YR |
| 221        | 6,189,690 | 32,423,150 | 0.19090 | \$44,723,515.00 | 777,364   | 8,537,871.66 | 0.01738 | \$148,401.44 | VALUE/LBS/YR |
|            | 1,650     | 244,049    | 0.00676 | \$349,503.00    | 82,274    | 2,162.87     | 0.23540 | \$542.65     | VALUE/LBS/YR |

|                 |           |            |         |                 |           |              |         |                           |
|-----------------|-----------|------------|---------|-----------------|-----------|--------------|---------|---------------------------|
| 269             | 52        | 1,028,577  | 0.00006 | \$3,140,250.00  | 525,766   | 189.20       | 0.16745 | \$11.69 VALUE/LBS/YR      |
| 512             | 448       | 292,555    | 0.00231 | \$691,178.00    | 131,257   | 1,596.96     | 0.16991 | \$303.25 VALUE/LBS/YR     |
| 012 (7064-7025) | 5,415     | 89,185     | 0.06072 | \$490,735.00    | 296,151   | 29,795.71    | 0.60348 | \$17,981.25 VALUE/LBS/YR  |
| 023             | 360       | 2,230      | 0.16143 | \$158,712.00    | 29,626    | 25,621.67    | 0.18667 | \$4,782.67 VALUE/LBS/YR   |
| 081             | 430,163   | 2,104,721  | 0.20438 | \$7,350,695.00  | 2,783,054 | 1,502,335.47 | 0.37861 | \$568,800.74 VALUE/LBS/YR |
| 096             | 2,346     | 82,768     | 0.02834 | \$195,476.00    | 63,998    | 5,540.63     | 0.32740 | \$1,813.98 VALUE/LBS/YR   |
| 120             | 24,565    | 472,063    | 0.05204 | \$2,558,483.00  | 1,673,090 | 133,137.18   | 0.65394 | \$87,063.50 VALUE/LBS/YR  |
| 121             | 45        | 1,103      | 0.04080 | \$19,710.00     | 15,063    | 804.13       | 0.76423 | \$614.54 VALUE/LBS/YR     |
| 122             | 39,240    | 460,775    | 0.08516 | \$1,737,096.00  | 1,373,343 | 147,932.61   | 0.79060 | \$126,955.09 VALUE/LBS/YR |
| 123             | 12,375    | 282,574    | 0.04379 | \$1,319,000.00  | 951,144   | 57,764.07    | 0.72111 | \$41,654.25 VALUE/LBS/YR  |
| 124             | 28,315    | 630,664    | 0.04490 | \$3,265,541.00  | 2,106,612 | 146,613.40   | 0.64510 | \$94,580.82 VALUE/LBS/YR  |
| 125             | 100       | 26,163     | 0.00382 | \$146,274.00    | 31,598    | 559.09       | 0.21602 | \$120.77 VALUE/LBS/YR     |
| 126             | 2,025     | 15,385     | 0.13162 | \$42,610.00     | 26,477    | 5,608.40     | 0.62138 | \$3,484.95 VALUE/LBS/YR   |
| 147             | 23,906    | 420,784    | 0.05681 | \$1,269,828.00  | 1,049,113 | 72,142.73    | 0.82619 | \$59,603.25 VALUE/LBS/YR  |
| 152             | 7,945     | 151,645    | 0.05239 | \$1,651,624.00  | 121,160   | 86,532.05    | 0.07336 | \$6,347.83 VALUE/LBS/YR   |
| 153             | 6,244     | 218,736    | 0.02855 | \$702,423.00    | 137,363   | 20,051.25    | 0.19556 | \$3,921.14 VALUE/LBS/YR   |
| 159             | 101       | 2,495      | 0.04046 | \$7,550.00      | 9,880     | 305.51       | 1.30861 | \$399.79 VALUE/LBS/YR     |
| 212             | 8,305     | 623,187    | 0.01333 | \$1,112,472.00  | 146,432   | 14,825.53    | 0.13163 | \$1,951.45 VALUE/LBS/YR   |
| 240             | 11,510    | 223,862    | 0.05142 | \$327,776.00    | 81,827    | 16,852.80    | 0.24954 | \$4,207.18 VALUE/LBS/YR   |
| 269             | 107,515   | 2,565,453  | 0.04191 | \$5,629,373.00  | 836,655   | 235,920.14   | 0.14862 | \$35,063.19 VALUE/LBS/YR  |
| 347             | 40        | 1,538      | 0.02601 | \$21,415.00     | 2,063     | 556.96       | 0.09633 | \$53.65 VALUE/LBS/YR      |
| 352             | 3,132,680 | 3,473,980  | 0.90176 | \$8,154,094.00  | 422,536   | 7,362,015.32 | 0.05052 | \$372,006.54 VALUE/LBS/YR |
| 509             | 833,805   | 2,594,856  | 0.32133 | \$9,819,091.00  | 1,114,256 | 3,155,168.21 | 0.11348 | \$358,043.85 VALUE/LBS/YR |
| 512             | 18,852    | 111,824    | 0.16859 | \$331,657.00    | 68,388    | 55,912.84    | 0.20620 | \$11,529.28 VALUE/LBS/YR  |
| 526             | 5,655     | 73,630     | 0.07680 | \$350,319.00    | 142,326   | 26,905.53    | 0.40628 | \$10,931.05 VALUE/LBS/YR  |
| 529             | 13,625    | 59,750     | 0.22832 | \$355,903.00    | 22,393    | 81,157.80    | 0.06292 | \$5,105.35 VALUE/LBS/YR   |
| 727             | 283       | 13,638     | 0.02075 | \$45,381.00     | 110,396   | 941.69       | 2.43265 | \$2,290.81 VALUE/LBS/YR   |
| 736             | 7,770     | 72,525     | 0.10714 | \$522,229.00    | 257,122   | 55,949.25    | 0.49235 | \$27,546.89 VALUE/LBS/YR  |
| 800             | 54,228    | 601,419    | 0.09017 | \$689,969.00    | 457,965   | 62,212.27    | 0.66375 | \$41,293.22 VALUE/LBS/YR  |
| 802             | 2,085     | 2,897      | 0.71971 | \$8,860.30      | 1,959     | 6,376.63     | 0.22111 | \$1,409.91 VALUE/LBS/YR   |
| 012 (7035)      | 1,720     | 89,185     | 0.01929 | \$490,735.00    | 296,151   | 9,464.19     | 0.60348 | \$5,711.50 VALUE/LBS/YR   |
| 081             | 25,916    | 2,104,721  | 0.01231 | \$7,350,695.00  | 2,783,054 | 90,511.10    | 0.37861 | \$34,268.50 VALUE/LBS/YR  |
| 096             | 328       | 82,768     | 0.00396 | \$195,476.00    | 63,998    | 774.65       | 0.32740 | \$253.62 VALUE/LBS/YR     |
| 120             | 14,005    | 472,063    | 0.02967 | \$2,558,483.00  | 1,673,090 | 75,904.18    | 0.65394 | \$49,636.65 VALUE/LBS/YR  |
| 122             | 23,945    | 460,775    | 0.04546 | \$1,737,096.00  | 1,373,343 | 78,961.48    | 0.79060 | \$62,426.71 VALUE/LBS/YR  |
| 123             | 4,425     | 282,574    | 0.01566 | \$1,319,000.00  | 951,144   | 20,655.13    | 0.72111 | \$14,894.55 VALUE/LBS/YR  |
| 124             | 13,125    | 630,664    | 0.02081 | \$3,265,541.00  | 2,106,612 | 67,960.48    | 0.64510 | \$43,841.54 VALUE/LBS/YR  |
| 126             | 2,605     | 15,385     | 0.16932 | \$42,610.00     | 26,477    | 7,214.76     | 0.62138 | \$4,483.11 VALUE/LBS/YR   |
| 147             | 4,880     | 420,784    | 0.01160 | \$1,269,828.00  | 1,049,113 | 14,726.70    | 0.82619 | \$12,166.98 VALUE/LBS/YR  |
| 152             | 5,400     | 151,645    | 0.03561 | \$1,651,624.00  | 121,160   | 58,813.48    | 0.07336 | \$4,314.44 VALUE/LBS/YR   |
| 153             | 958       | 218,736    | 0.00438 | \$702,423.00    | 137,363   | 3,076.41     | 0.19556 | \$601.61 VALUE/LBS/YR     |
| 168             | 179,620   | 11,845,426 | 0.01516 | \$19,902,069.00 | 893,872   | 301,788.19   | 0.04491 | \$13,554.37 VALUE/LBS/YR  |
| 212             | 3,515     | 94,316     | 0.03727 | \$1,112,472.00  | 146,432   | 41,459.98    | 0.13163 | \$5,457.28 VALUE/LBS/YR   |
| 240             | 3,330     | 223,862    | 0.01488 | \$327,776.00    | 81,827    | 4,875.75     | 0.24954 | \$1,217.20 VALUE/LBS/YR   |
| 269             | 409       | 2,565,453  | 0.00016 | \$5,629,373.00  | 836,655   | 897.47       | 0.14862 | \$133.38 VALUE/LBS/YR     |
| 347             | 490       | 1,538      | 0.31860 | \$21,415.00     | 2,063     | 6,822.72     | 0.09633 | \$657.26 VALUE/LBS/YR     |
| 365             | 318       | 43,227     | 0.00736 | \$461,163.00    | 27,900    | 3,392.55     | 0.06050 | \$205.25 VALUE/LBS/YR     |
| 509             | 57,565    | 2,594,856  | 0.02218 | \$9,819,091.00  | 1,114,256 | 217,829.42   | 0.11348 | \$24,718.96 VALUE/LBS/YR  |
| 512             | 1,734     | 111,824    | 0.01551 | \$331,657.00    | 68,388    | 5,142.84     | 0.20620 | \$1,060.46 VALUE/LBS/YR   |
| 526             | 3,130     | 73,630     | 0.04251 | \$350,319.00    | 142,326   | 14,892.01    | 0.40628 | \$6,050.26 VALUE/LBS/YR   |
| 529             | 1,000     | 59,750     | 0.01674 | \$355,903.00    | 22,393    | 5,956.54     | 0.06292 | \$374.78 VALUE/LBS/YR     |
| 727             | 353       | 13,638     | 0.02588 | \$45,381.00     | 110,396   | 1,174.62     | 2.43265 | \$2,857.44 VALUE/LBS/YR   |
| 736             | 2,300     | 72,525     | 0.03171 | \$522,229.00    | 257,122   | 16,561.55    | 0.49235 | \$8,154.16 VALUE/LBS/YR   |
| 012 (7045)      | 20        | 89,185     | 0.00022 | \$490,735.00    | 296,151   | 110.05       | 0.60348 | \$66.41 VALUE/LBS/YR      |
| 081             | 13,339    | 2,104,721  | 0.00634 | \$7,350,695.00  | 2,783,054 | 46,586.18    | 0.37861 | \$17,638.04 VALUE/LBS/YR  |

|     |           |            |         |                 |           |              |         |             |              |
|-----|-----------|------------|---------|-----------------|-----------|--------------|---------|-------------|--------------|
| 11  | 1.305     | 460.775    | 0.00293 | \$1,737.095.00  | 1.373.343 | 4,919.76     | 0.79260 | \$3,889.55  | VALUE/LBS/YR |
| 12  | 1.081     | 282.574    | 0.00736 | \$1,319.035.00  | 951.144   | 9,709.08     | 0.72111 | \$7,031.26  | VALUE/LBS/YR |
| 14  | 1.715     | 630.454    | 0.00272 | \$3,255.541.00  | 2,106.612 | 8,350.17     | 0.64510 | \$5,705.63  | VALUE/LBS/YR |
| 15  | 200       | 16.153     | 0.00764 | \$146,274.00    | 31.598    | 1,118.17     | 0.21602 | \$241.55    | VALUE/LBS/YR |
| 167 | 51        | 420.784    | 0.00012 | \$1,259,825.00  | 1,049.113 | 153.91       | 0.82519 | \$127.15    | VALUE/LBS/YR |
| 168 | 889.930   | 11,845,426 | 0.07513 | \$19,902,059.00 | 893.872   | 1,495,163.72 | 0.04491 | \$67,153.07 | VALUE/LBS/YR |
| 221 | 3,977.840 | 43,134,180 | 0.09222 | \$52,152,510.00 | 1,043.330 | 4,809,511.63 | 0.02001 | \$95,215.04 | VALUE/LBS/YR |
| 240 | 100       | 223.862    | 0.00345 | \$327,776.00    | 81.827    | 145.42       | 0.24964 | \$36.55     | VALUE/LBS/YR |
| 259 | 23        | 2,555.380  | 0.00001 | \$5,629,373.00  | 836,655   | 50.47        | 0.14552 | \$7.50      | VALUE/LBS/YR |
| 512 | 336       | 111.824    | 0.00300 | \$331,657.00    | 68,388    | 996.54       | 0.20520 | \$295.49    | VALUE/LBS/YR |
| 526 | 125       | 73.630     | 0.00170 | \$350,319.00    | 142,326   | 594.73       | 0.40628 | \$241.62    | VALUE/LBS/YR |

# YEARLY TOTAL

|              |            |             |                |                |
|--------------|------------|-------------|----------------|----------------|
| 1982 ALL-LBS | 32,116,499 | 1982 ALL-\$ | \$3,489,272.13 | TOTAL VALUE-82 |
| 1983 ALL-LBS | 43,568,035 | 1983 ALL-\$ | \$3,198,669.47 | TOTAL VALUE-83 |
| 1984 ALL-LBS | 41,937,628 | 1984 ALL-\$ | \$2,451,806.75 | TOTAL VALUE-84 |

# 10 MIN TOTALS

| YEAR | LATITUDE | LONGITUDE | TOTAL-\$/10 MIN |                                |
|------|----------|-----------|-----------------|--------------------------------|
| 1982 | 4225     | 7025      | 18,206,662      | \$3,219,655.82 TOTAL-\$/10 MIN |
|      | 4225     | 7035      | 13,909,837      | \$210,502.15 TOTAL-\$/10 MIN   |
|      | 4225     | 7045      | 0               | \$0.00 TOTAL-\$/10 MIN         |
| 1983 | 4225     | 7025      | 15,340,928      | \$2,465,414.05 TOTAL-\$/10 MIN |
|      | 4225     | 7035      | 15,790,825      | \$539,733.59 TOTAL-\$/10 MIN   |
|      | 4225     | 7045      | 12,436,281      | \$193,521.83 TOTAL-\$/10 MIN   |
| 1984 | 4225     | 7025      | 14,321,990      | \$1,879,557.94 TOTAL-\$/10 MIN |
|      | 4225     | 7035      | 14,285,135      | \$297,040.00 TOTAL-\$/10 MIN   |
|      | 4225     | 7045      | 13,330,503      | \$285,208.81 TOTAL-\$/10 MIN   |



APPENDIX B: Table III A-3  
LANDINGS AND VALUE

AREA 514  
1972 - 1974

| SPECIES            | 1972           |                | 1973           |                | 1974           |                | 1972        | 1973        | 1974        |
|--------------------|----------------|----------------|----------------|----------------|----------------|----------------|-------------|-------------|-------------|
|                    | LANDINGS - LBS | VALUE          | LANDINGS - LBS | VALUE          | LANDINGS - LBS | VALUE          | % TOTAL LBS | % TOTAL LBS | % TOTAL LBS |
| ALEWIFE (001)      | 0              | \$0.00         | 550.200        | \$11,575.00    | 121.935        | \$5,416.00     | 0.00%       | 0.64%       | 0.14%       |
| ANGLER (012)       | 219.080        | \$12,675.00    | 376.142        | \$41,378.00    | 562.747        | \$76,715.00    | 0.20%       | 0.44%       | 0.53%       |
| NEEDLEFISH (019)   | 0              | \$0.00         | 1.195          | \$186.00       | 0              | \$0.00         | 0.00%       | 0.00%       | 0.00%       |
| NEEDLEFISH (021)   | 77.505         | \$13,680.00    | 0              | \$0.00         | 0              | \$0.00         | 0.07%       | 0.00%       | 0.00%       |
| BLUEFISH (023)     | 0              | \$0.00         | 120.376        | \$27,529.00    | 115.055        | \$15,311.00    | 0.00%       | 0.14%       | 0.13%       |
| BONITO (033)       | 0              | \$0.00         | 0              | \$0.00         | 1,597          | \$386.00       | 0.00%       | 0.00%       | 0.00%       |
| BUTTERFISH (051)   | 0              | \$0.00         | 3.457          | \$1,064.00     | 8.332          | \$1,449.00     | 0.00%       | 0.00%       | 0.00%       |
| BUTTERFISH (052)   | 55.550         | \$9,604.00     | 0              | \$0.00         | 0              | \$0.00         | 0.05%       | 0.00%       | 0.00%       |
| COD (081)          | 6,509,507      | \$1,122,557.00 | 6,409,571      | \$1,243,946.00 | 6,752,990      | \$1,281,359.00 | 5.86%       | 7.47%       | 7.61%       |
| CUSE (096)         | 622.727        | \$58,702.00    | 1,067,172      | \$128,706.00   | 1,117,005      | \$162,501.00   | 0.56%       | 1.24%       | 1.25%       |
| CUSE (114)         | 0              | \$0.00         | 3,587          | \$1,223.00     | 315            | \$187.00       | 0.00%       | 0.00%       | 0.00%       |
| S. FLOCH (121)     | 750.700        | \$193,999.00   | 649            | \$277.00       | 58,617         | \$12,496.00    | 0.68%       | 0.00%       | 0.07%       |
| WITCH P. (122)     | 23,435         | \$7,465.00     | 770.077        | \$258,611.00   | 469,422        | \$181,181.00   | 0.02%       | 0.90%       | 0.53%       |
| YELLOWTAIL (123)   | 1,903,388      | \$415,587.00   | 2,264,518      | \$551,883.00   | 2,594,579      | \$674,696.00   | 1.71%       | 2.64%       | 2.93%       |
| AMER PLATICH (124) | 0              | \$0.00         | 451.973        | \$84,593.00    | 962,589        | \$150,700.00   | 0.00%       | 0.53%       | 1.00%       |
| WF S BAR (125)     | 0              | \$0.00         | 0              | \$0.00         | 255            | \$134.00       | 0.00%       | 0.00%       | 0.00%       |
| HALIBUT (147)      | 715.395        | \$284,985.00   | 476,046        | \$207,061.00   | 446,329        | \$198,946.00   | 0.64%       | 0.55%       | 0.51%       |
| RED HAKE (152)     | 643.390        | \$34,699.00    | 421.375        | \$27,381.00    | 651,360        | \$36,338.00    | 0.58%       | 0.49%       | 0.73%       |
| WHITE HAKE (153)   | 592.174        | \$58,269.00    | 1,040,529      | \$100,354.00   | 1,213,245      | \$124,901.00   | 0.62%       | 1.21%       | 1.37%       |
| HALIBUT (159)      | 30.084         | \$21,403.00    | 42.376         | \$42,526.00    | 41.389         | \$52,308.00    | 0.03%       | 0.05%       | 0.05%       |
| SEA HERRING (168)  | 37,455,380     | \$732,849.00   | 3,945,600      | \$127,433.00   | 10,763,330     | \$349,135.00   | 33.72%      | 4.60%       | 12.14%      |
| HAVEREL (212)      | 1,956,876      | \$133,088.00   | 555,437        | \$88,315.00    | 339,138        | \$93,730.00    | 1.76%       | 0.65%       | 0.39%       |
| HEMLOCK (221)      | 11,289,297     | \$175,197.00   | 41,428,345     | \$829,061.00   | 42,013,817     | \$650,000.00   | 10.16%      | 48.30%      | 71.99%      |
| REDFISH (240)      | 225,825        | \$12,083.00    | 338,170        | \$24,403.00    | 201,090        | \$14,446.00    | 0.20%       | 0.35%       | 0.23%       |
| POLLOCK (269)      | 3,939,770      | \$228,846.00   | 3,804,574      | \$282,647.00   | 3,914,167      | \$317,097.00   | 3.55%       | 4.44%       | 4.41%       |
| SALMON (305)       | 0              | \$0.00         | 25             | \$25.00        | 28             | \$35.00        | 0.00%       | 0.00%       | 0.00%       |
| SCULPIN (326)      | 0              | \$0.00         | 0              | \$0.00         | 420            | \$84.00        | 0.00%       | 0.00%       | 0.00%       |
| SCUP (329)         | 802            | \$221.00       | 88             | \$31.00        | 8,258          | \$2,695.00     | 0.00%       | 0.00%       | 0.01%       |
| B.S. BASS (335)    | 290            | \$179.00       | 336            | \$133.00       | 2,869          | \$1,201.00     | 0.00%       | 0.00%       | 0.00%       |
| B.S. BASS (336)    | 52             | \$17.00        | 0              | \$0.00         | 0              | \$0.00         | 0.00%       | 0.00%       | 0.00%       |
| SEA ROBINS (342)   | 0              | \$0.00         | 0              | \$0.00         | 386            | \$28.00        | 0.00%       | 0.00%       | 0.00%       |
| SQUETEAGUE (344)   | 0              | \$0.00         | 0              | \$0.00         | 4,995          | \$758.00       | 0.00%       | 0.00%       | 0.00%       |
| SHAD (347)         | 375            | \$27.00        | 652            | \$87.00        | 1,281          | \$138.00       | 0.00%       | 0.00%       | 0.00%       |
| EGGFISH (350)      | 5,118          | \$302.00       | 10,838         | \$655.00       | 6,950          | \$494.00       | 0.00%       | 0.01%       | 0.01%       |
| SKATES WK (365)    | 105,125        | \$7,848.00     | 116,659        | \$9,548.00     | 104,945        | \$9,452.00     | 0.10%       | 0.14%       | 0.12%       |
| STRIPED B. (418)   | 108,229        | \$39,740.00    | 112,684        | \$53,626.00    | 120,261        | \$55,812.00    | 0.10%       | 0.13%       | 0.14%       |
| STURGEONS (421)    | 2,083          | \$233.00       | 1,560          | \$203.00       | 2,004          | \$281.00       | 0.00%       | 0.00%       | 0.00%       |
| SWORDFISH (432)    | 0              | \$0.00         | 0              | \$0.00         | 4,877          | \$5,657.00     | 0.00%       | 0.00%       | 0.01%       |
| TACUOG (447)       | 14,123         | \$877.00       | 7,884          | \$928.00       | 7,960          | \$493.00       | 0.01%       | 0.01%       | 0.01%       |
| TELEFISH (447)     | 0              | \$0.00         | 0              | \$0.00         | 1,139          | \$188.00       | 0.00%       | 0.00%       | 0.00%       |
| LITTLE TUNA (465)  | 566,318        | \$71,638.00    | 1,195,282      | \$512,355.00   | 609,006        | \$355,476.00   | 0.51%       | 1.39%       | 0.69%       |
| SILVER HAKE (509)  | 4,727,510      | \$447,763.00   | 7,650,734      | \$526,885.00   | 5,896,049      | \$504,473.00   | 4.26%       | 8.92%       | 6.55%       |
| WOLFFISHES (512)   | 181,250        | \$11,329.00    | 228,678        | \$13,090.00    | 287,996        | \$17,641.00    | 0.16%       | 0.27%       | 0.32%       |
| FISH POGE (526)    | 31,900,331     | \$582,314.00   | 5,029,451      | \$1,078,682.00 | 4,741,103      | \$821,902.00   | 28.72%      | 5.85%       | 5.35%       |
| FISH IND (529)     | 419,690        | \$5,872.00     | 656,479        | \$19,383.00    | 273,935        | \$9,947.00     | 0.38%       | 0.77%       | 0.31%       |
| LOBSTER (727)      | 0              | \$0.00         | 612            | \$709.00       | 83             | \$128.00       | 0.00%       | 0.00%       | 0.00%       |
| SHRIMP (736)       | 1,875,134      | \$309,645.00   | 2,738,955      | \$688,282.00   | 2,155,585      | \$561,371.00   | 1.69%       | 3.19%       | 2.43%       |
| S SCALLOPS (800)   | 1,582,293      | \$375,624.00   | 1,748,351      | \$391,919.00   | 389,066        | \$79,581.00    | 1.42%       | 2.04%       | 0.44%       |
| SQUIDS (803)       | 69,690         | \$5,918.00     | 91,380         | \$10,527.00    | 136,932        | \$12,812.00    | 0.06%       | 0.11%       | 0.15%       |
| WIK FLOCH (126)    | 2,405,941      | \$469,525.00   | 2,144,355      | \$497,235.00   | 1,654,082      | \$380,992.00   | 2.17%       | 2.50%       | 1.88%       |

|        |             |               |            |                |            |                |         |         |         |
|--------|-------------|---------------|------------|----------------|------------|----------------|---------|---------|---------|
| TOTALS | 111,075,636 | 85,651,771.00 | 85,777,362 | \$7,873,915.00 | 88,681,949 | \$7,230,183.00 | 100.00% | 100.00% | 100.00% |
|--------|-------------|---------------|------------|----------------|------------|----------------|---------|---------|---------|

APPENDIX B  
Table III A-4  
LANDINGS AND VALUE  
AREA 514  
1982 - 1984

| SPECIES            | 1982               | 1983           | 1984               | 1982           | 1983               | 1984           |
|--------------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|
|                    | LANDINGS<br>POUNDS | VALUE<br>\$    | LANDINGS<br>POUNDS | VALUE<br>\$    | LANDINGS<br>POUNDS | VALUE<br>\$    |
| ANGLER (012)       | 522.068            | \$302,407.00   | 456.681            | \$263,303.00   | 490.735            | \$295,151.00   |
| BUTTERFISH (023)   | 432.898            | \$75,516.00    | 255.335            | \$36,873.00    | 158.712            | \$29,626.00    |
| BUTTERFISH (051)   | 76.822             | \$29,385.00    | 64.244             | \$25,424.00    | 53.427             | \$22,850.00    |
| COD (081)          | 13,398.573         | \$4,520,839.00 | 14,124,290         | \$4,942,412.00 | 7,350.695          | \$2,783,859.00 |
| CUSE (096)         | 275,994            | \$53,224.00    | 188,732            | \$51,126.00    | 195,476            | \$53,998.00    |
| DB HERR (112)      | 0                  | \$0.00         | 0                  | \$0.00         | 110,840            | \$2,216.00     |
| DEL AMER (115)     | 450                | \$23.00        | 0                  | \$0.00         | 470                | \$18.00        |
| DEL CONG (116)     | 25                 | \$4.00         | 0                  | \$0.00         | 0                  | \$0.00         |
| W. FLOUNDER (120)  | 3,830.162          | \$1,601,279.00 | 2,935,176          | \$1,299,410.00 | 2,558,483          | \$1,673,090.00 |
| S. FLOUNDER (121)  | 204.833            | \$154,828.00   | 41,983             | \$30,506.00    | 19,710             | \$15,063.00    |
| WH. FLOUNDER (122) | 941.249            | \$621,986.00   | 1,055,740          | \$687,120.00   | 1,737,096          | \$1,373,343.00 |
| YELLOWTAIL (123)   | 3,864,544          | \$2,103,718.00 | 2,183,859          | \$1,150,443.00 | 1,319,006          | \$951,144.00   |
| AM PLATICE (124)   | 5,615,917          | \$2,592,627.00 | 4,570,713          | \$2,151,215.00 | 3,255,541          | \$2,106,612.00 |
| SAND DAB (125)     | 186,662            | \$27,210.00    | 117,154            | \$17,480.00    | 146,274            | \$31,598.00    |
| FLOUNDER (126)     | 66,613             | \$31,453.00    | 31,346             | \$12,413.00    | 42,610             | \$26,477.00    |
| POWERSHOT (127)    | 3,545              | \$400.00       | 3,214              | \$394.00       | 1,685              | \$216.00       |
| HADDOCK (147)      | 1,393,004          | \$752,778.00   | 1,652,751          | \$1,025,561.00 | 1,269,828          | \$1,049,113.00 |
| REC HAYE (152)     | 1,889,195          | \$252,400.00   | 1,551,445          | \$135,379.00   | 1,551,624          | \$121,160.00   |
| WHITE HAYE (153)   | 630,942            | \$127,303.00   | 583,600            | \$106,550.00   | 702,423            | \$137,363.00   |
| HALIBUT (159)      | 15,072             | \$17,111.00    | 9,246              | \$9,418.00     | 7,550              | \$9,880.00     |
| S HERRING (160)    | 11,052,013         | \$497,564.00   | 5,658,106          | \$250,090.00   | 19,932,069         | \$893,872.00   |
| HACKEREL (212)     | 392,769            | \$98,828.00    | 876,670            | \$236,978.00   | 1,112,472          | \$146,432.00   |
| HEWHADE (221)      | 21,304,180         | \$439,688.00   | 44,723,525         | \$777,364.00   | 52,152,510         | \$1,043,330.00 |
| REEFISH (240)      | 385,802            | \$104,149.00   | 349,503            | \$82,274.00    | 327,776            | \$81,827.00    |
| OCEAN POUT (250)   | 465,325            | \$21,752.00    | 694,397            | \$51,556.00    | 2,098,042          | \$190,387.00   |
| POLLACK (269)      | 3,355,303          | \$648,022.00   | 3,140,250          | \$525,766.00   | 5,629,373          | \$836,655.00   |
| SALMON (305)       | 0                  | \$0.00         | 0                  | \$0.00         | 9                  | \$20.00        |
| SCUP (329)         | 5,429              | \$1,550.00     | 7,239              | \$4,078.00     | 505                | \$458.00       |
| B.S. BASS (335)    | 4,194              | \$6,886.00     | 3,424              | \$5,924.00     | 4,169              | \$9,120.00     |
| SQUATRAQUE (344)   | 20                 | \$12.00        | 0                  | \$0.00         | 76                 | \$34.00        |
| SHAD (347)         | 5,663              | \$620.00       | 5,797              | \$557.00       | 21,415             | \$2,063.00     |
| DOGFISH (350)      | 308,110            | \$20,038.00    | 0                  | \$0.00         | 0                  | \$0.00         |
| DE. SMOOTH (351)   | 0                  | \$0.00         | 42                 | \$11.00        | 0                  | \$0.00         |
| DE. SPINNY (352)   | 6,028,066          | \$396,748.00   | 9,986,350          | \$630,301.00   | 8,164,094          | \$412,536.00   |
| SERPHEAD (356)     | 0                  | \$0.00         | 0                  | \$0.00         | 48                 | \$1.00         |
| SERPHEAD (357)     | 2,947              | \$1,821.00     | 1,969              | \$1,360.00     | 7,062              | \$729.00       |
| SHARK WK (359)     | 6,099              | \$3,834.00     | 4,013              | \$2,205.00     | 842                | \$792.00       |
| SILVERSIDE (362)   | 40                 | \$4.00         | 0                  | \$0.00         | 0                  | \$0.00         |
| SEATES WK (365)    | 235,376            | \$23,397.00    | 454,931            | \$27,083.00    | 461,163            | \$27,900.00    |
| STRIP BASS (418)   | 6,024              | \$8,628.00     | 2,581              | \$6,143.00     | 1,088              | \$2,163.00     |
| STURGEONS (421)    | 1,285              | \$324.00       | 1,622              | \$480.00       | 3,292              | \$885.00       |
| SWORDFISH (432)    | 0                  | \$0.00         | 85                 | \$285.00       | 0                  | \$0.00         |
| TAUPOG (438)       | 15,189             | \$2,145.00     | 9,360              | \$1,240.00     | 6,551              | \$1,150.00     |
| TITFISH (447)      | 27                 | \$4.00         | 332                | \$122.00       | 512                | \$235.00       |
| WHA BL (467)       | 468,441            | \$1,068,601.00 | 1,018,297          | \$3,035,815.00 | 637,128            | \$2,283,102.00 |
| WHA PR (506)       | 0                  | \$0.00         | 125                | \$50.00        | 780                | \$286.00       |
| S WAKE (509)       | 4,953,697          | \$991,771.00   | 7,499,013          | \$951,649.00   | 9,819,091          | \$1,114,255.00 |
| WOLFFISH (512)     | 399,513            | \$77,597.00    | 691,178            | \$131,262.00   | 331,657            | \$68,388.00    |

|                    |            |                 |             |                 |             |                 |         |         |         |
|--------------------|------------|-----------------|-------------|-----------------|-------------|-----------------|---------|---------|---------|
| CL. FISH (500)     | 592.489    | \$229,491.00    | 776.185     | \$282,941.00    | 350.319     | \$142,326.00    | 0.68%   | 0.71%   | 0.15%   |
| OYSTER INC (500)   | 106.635    | \$10,916.00     | 31.775      | \$1,393.00      | 355.903     | \$22,393.00     | 0.15%   | 0.03%   | 0.29%   |
| LOBSTER (700)      | 26.035     | \$71,371.00     | 17.307      | \$42,573.00     | 45.381      | \$10,396.00     | 0.03%   | 0.02%   | 0.04%   |
| SEALINE (736)      | 1,056.574  | \$496,616.00    | 597.870     | \$303,254.00    | 522.129     | \$257,122.00    | 1.20%   | 0.55%   | 0.42%   |
| B. EYE TONGUE (69) | 1,249.076  | \$209,082.00    | 736.610     | \$67,904.00     | 205.597     | \$21,365.00     | 2.55%   | 0.68%   | 0.17%   |
| CONCES (775)       | 1.476      | \$231.00        | 0           | \$0.00          | 31          | \$2.00          | 0.00%   | 0.00%   | 0.00%   |
| SEA SCAL (800)     | 1,165.742  | \$621,620.00    | 1,764.496   | \$1,163,809.00  | 689,969     | \$457,965.00    | 1.35%   | 1.62%   | 0.56%   |
| SQUID LIL (801)    | 9.592      | \$3,840.00      | 54.671      | \$18,823.00     | 34.415      | \$15,967.00     | 0.01%   | 0.05%   | 0.03%   |
| SQUID LIL (802)    | 135,014    | \$16,616.00     | 3,713       | \$915.00        | 8,860       | \$1,959.00      | 0.15%   | 0.00%   | 0.01%   |
| SQUID (NS) (803)   | 2,510      | \$453.00        | 3,395       | \$1,730.00      | 1,617       | \$436.00        | 0.00%   | 0.00%   | 0.00%   |
| TOTALS:            | 82,145,235 | \$19,629,841.00 | 108,952,352 | \$20,482,064.00 | 123,972,150 | \$18,840,350.00 | 100.00% | 100.00% | 100.00% |

Table III.B-1

## Calculation of REMOTS Organism-Sediment Index

The REMOTS Organism-Sediment Index is arrived at by summing the subset indices below:

| <u>Mean RPD Depth</u> | <u>Index Value</u> |
|-----------------------|--------------------|
| > 0 - 0.75 cm         | 1                  |
| 0.76 - 1.50 cm        | 2                  |
| 1.51 - 2.25 cm        | 3                  |
| 2.26 - 3.00 cm        | 4                  |
| 3.01 - 3.75 cm        | 5                  |
| > 3.75 cm             | 6                  |

| <u>Chemical Parameters</u> | <u>Index Value</u> |
|----------------------------|--------------------|
| Methane present            | -2                 |
| No/low dissolved oxygen    | -4                 |

| <u>Successional Stage</u><br>(primary succession) | <u>Index Value</u> |
|---|--------------------|
| Azoic   | -4                 |
| Stage 1   | 1                  |
| Stage 1-2   | 2                  |
| Stage 2   | 3                  |
| Stage 2-3   | 4                  |
| Stage 3   | 5                  |

| <u>Successional Stage</u><br>(secondary succession) | <u>Index Value</u> |
|---|--------------------|
| Stage 1 on a Stage 3                                | 5                  |
| Stage 2 on a Stage 3                                | 5                  |

REMOTS ORGANISM-SEDIMENT INDEX = -----  
Total of all  
subset indices

RANGE : -10 to +11

Table III.B-2

Summary Of Benthic Sampling  
Parameters At FADS For June And September Cruises,  
1985 And January 1986

| <u>Date</u>       | <u>Station<br/>Sampled</u>          | <u>Coordinates</u>       | <u>Depth</u> | <u>#Smith-McIntyre<br/>Grab Samples<br/>For Benthic<br/>Analysis</u><br>4 | <u># Grab<br/>Samples<br/>Analyzed</u><br>3 | <u># Biological<br/>Core Samples<br/>For Fine<br/>Sieving</u><br>1 |
|-------------------|-------------------------------------|--------------------------|--------------|---|---|--|
| 6/6/85            | Mud<br>Reference<br>(18-17)         | 42°24.686N<br>70°32.814W | 92m          |   |   |  |
| 10/7 -<br>10/8/85 | Sand<br>Reference<br>*              | 42°25.497N<br>70°31.755W | 76m          | 6   | 3   | 1  |
|                   | Sand<br>Station<br>(5-9)            | 42°26.443N<br>70°34.274W | 50m          | 6   | 3   | 1  |
|                   | Mud<br>Station<br>On DM<br>(9-8)    | 42°25.903N<br>70°34.456W | 78m          | 6   | 3   | 1  |
|                   | Mud<br>Station<br>Off DM<br>(16-11) | 42°24.956N<br>70°33.909W | 84m          | 6   | 3   | 1  |
|                   | Mud<br>Reference<br>(18-17)         | 42°24.686N<br>70°32.814W | 92m          | 6   | 3   | 1  |
| 1/31/86           | Sand<br>Reference<br>*              | 42°25.497N<br>70°31.755W | 76m          | 5   | 3   | 0  |
|                   | Mud<br>Reference<br>(18-17)         | 42°24.686N<br>70°32.814W | 92m          | 5   | 3   | 0  |

\* 700 meters east of station 12-20

TABLE III.B-3  
RPD Depths At FADS

| <u>DATA SET</u>  | Mean Value<br>(Number of Samples) |                      |                     | Among-<br>Season<br>ANOVA<br><u>Results</u> |
|--|-----------------------------------|----------------------|---------------------|---|
|  | June<br><u>1985</u>               | Sept.<br><u>1985</u> | Jan.<br><u>1986</u> |   |
| Entire FADS Area   | 4.92<br>(106)                     | 5.59<br>(155)        | 3.52<br>(92)        | p<.001                                      |
| On Dredged Material                                      | 4.96<br>(32)                      | 5.12<br>(27)         | 2.64<br>(47)        | p<.001                                      |
| Within Site, Off<br>Dredged Material                     | 4.73<br>(39)                      | 6.22<br>(30)         | 4.15<br>(33)        | p<.001                                      |
| Reference Area<br>(SE Quadrant Outside<br>Disposal Site) | 3.99<br>(11)                      | 5.81<br>(47)         | 5.45<br>(10)        | p=.02                                       |

NOTE: Results of Scheffé test on ANOVA results are indicated by solid line; those values with solid line underneath are not significantly different from each other.

Table III.B-4

Summary Of Grain Size And Wentworth Size Class Of Sediments  
From Sampling Stations (Grid Location) At FADS

| <u>Sampling Location<br/>Date and Replicate</u>               | <u>Median Grain Size<br/>(mm) (50% finer)</u> | <u>Wentworth Class<br/>Size</u> |
|---|---|---------------------------------|
| Mud Reference (18-17)<br>June, 1985                           |   |                                 |
| 1   | 0.0080  | Fine Silt                       |
| 2   | 0.0090  | Fine Silt                       |
| 3   | 0.0120  | Fine Silt                       |
| Sand Reference*<br>September 1985                             |   |                                 |
| 1   | 1.000   | Very Coarse Sand                |
| 2   | 0.7000  | Coarse Sand                     |
| 3   | 0.5000  | Coarse Sand                     |
| Sand Station (5-9)<br>September 1985                          |   |                                 |
| 1   | 0.4200  | Medium Sand                     |
| 2   | 0.7000  | Coarse Sand                     |
| 3   | 0.7500  | Coarse Sand                     |
| Mud Station on Dredged<br>Material (9-8)<br>September 1985    |   |                                 |
| 1   | 0.0130  | Fine Silt                       |
| 2   | 0.0150  | Fine Silt                       |
| 3   | 0.0170  | Medium Silt                     |
| Mud Station Off<br>Dredged Material (16-11)<br>September 1985 |   |                                 |
| 1   | 0.0120  | Fine Silt                       |
| 2   | 0.0095  | Fine Silt                       |
| 3   | 0.0120  | Fine Silt                       |



Table III.B-4 (continued)

| <u>Sampling Location<br/>Date and Replicate</u> | <u>Median Grain Size<br/>(mm) (50% finer)</u> | <u>Wentworth Class<br/>Size</u> |
|---|---|---------------------------------|
| Mud Reference (18-17)<br>September 1985         |   |                                 |
| 1   | 0.0100  | Fine Silt                       |
| 2   | 0.0120  | Fine Silt                       |
| 3   | 0.0120  | Fine Silt                       |
| Sand Reference*                                 |   |                                 |
| January 1986                                    |   |                                 |
| 1   | 0.400   | Medium Sand                     |
| 2   | 0.520   | Coarse Sand                     |
| 3   | 0.400   | Medium Sand                     |
| Mud Reference (18-17)<br>January 1986           |   |                                 |
| 1   | 0.0090  | Fine Silt                       |
| 2   | 0.0075  | Very Fine Silt                  |
| 3   | 0.0070  | Very Fine Silt                  |

\*700 meters east of Station 12-20.

TABLE III.B-5  
Number Of Replicate Samples Needed At Four Levels Of  
Precision For Population Densities Of Dominant Taxa At FADS

| SPECIES                          | LEVEL OF PRECISION |            |            |            |
|----------------------------------|--------------------|------------|------------|------------|
|                                  | <u>.10</u>         | <u>.20</u> | <u>.30</u> | <u>.40</u> |
| Annelida                         |                    |            |            |            |
| <u>Oligochaeta sp.</u>           | 18                 | 5          | 2          | 1          |
| Polychaeta                       |                    |            |            |            |
| Ampharetidae                     |                    |            |            |            |
| <u>Anobothrus gracilis</u>       | 34                 | 8          | 4          | 2          |
| Capitellidae                     |                    |            |            |            |
| <u>Heteromastus filiformis</u>   | 54                 | 13         | 6          | 3          |
| <u>Mediomastus ambiseta</u>      | 31                 | 8          | 3          | 2          |
| Cirratulidae                     |                    |            |            |            |
| <u>Chaetozone setosa</u>         | 29                 | 7          | 3          | 2          |
| Paraonidae                       |                    |            |            |            |
| <u>Levinsenia gracilis</u>       | 39                 | 10         | 4          | 2          |
| <u>Aricidea quadrilobata</u>     | 24                 | 6          | 3          | 2          |
| Spionidae                        |                    |            |            |            |
| <u>Prionospio steenstrupi</u>    | 26                 | 7          | 3          | 2          |
| <u>Spio pettibonae</u>           | 23                 | 6          | 3          | 1          |
| Syllidae                         |                    |            |            |            |
| <u>Exogone verugera profunda</u> | 36                 | 9          | 4          | 2          |
| Mollusca                         |                    |            |            |            |
| Bivalvia                         |                    |            |            |            |
| Thyasiridae                      |                    |            |            |            |
| <u>Thyasira flexuosa</u>         | 45                 | 11         | 5          | 3          |

TABLE III.B-6

Comparison Of 1.0mm And 0.5mm Size Fractions From FADS Infaunal  
Samples From The June And September 1985 Surveys.  
(Total individuals are reported as no./m<sup>2</sup>)

| REPLICATE                            | 1     |       | 2     |       | 3     |       |
|--------------------------------------|-------|-------|-------|-------|-------|-------|
| SIEVE FRACTION (mm)                  | 1.0   | 0.5   | 1.0   | 0.5   | 1.0   | 0.5   |
| Mud Ref - June 1985                  |       |       |       |       |       |       |
| Species/Fraction                     | 27    | 28    | 22    | 21    | 23    | 22    |
| Species/Sample                       | 40    |       | 33    |       | 33    |       |
| Individual/Fraction                  | 2980  | 2200  | 1430  | 1540  | 2140  | 2210  |
| Total Individuals                    | 5400  |       | 3096  |       | 4535  |       |
| Mud Ref - Sept. 1985                 |       |       |       |       |       |       |
| Species/Fraction                     | 35    | 33    | 34    | 29    | 29    | 24    |
| Species/Sample                       | 49    |       | 43    |       | 37    |       |
| Individual/Fraction                  | 3900  | 4840  | 5480  | 2690  | 6540  | 3080  |
| Total Individuals                    | 9111  |       | 8517  |       | 10028 |       |
| Mud Station Off DM<br>September 1985 |       |       |       |       |       |       |
| Species/Fraction                     | 31    | 28    | 32    | 25    | 30    | 16    |
| Species/Sample                       | 43    |       | 37    |       | 32    |       |
| Individuals/Fraction                 | 4040  | 5330  | 7480  | 2690  | 4540  | 1090  |
| Total Individuals                    | 9768  |       | 10602 |       | 5869  |       |
| Mud Station On DM<br>September 1985  |       |       |       |       |       |       |
| Species/Fraction                     | 24    | 46    | 46    | 44    | 40    | 39    |
| Species/Sample                       | 49    |       | 62    |       | 53    |       |
| Individuals/Fraction                 | 1420  | 13000 | 9310  | 22190 | 14520 | 15960 |
| Total Individuals                    | 15032 |       | 32837 |       | 31774 |       |
| Sand Ref - Sept. 1985                |       |       |       |       |       |       |
| Species/Fraction                     | 67    | 38    | 44    | 35    | 46    | 34    |
| Species/Sample                       | 76    |       | 56    |       | 58    |       |
| Individual/Fraction                  | 5680  | 6060  | 3010  | 5150  | 3480  | 3070  |
| Total Individuals                    | 12238 |       | 8506  |       | 6828  |       |
| Sand Station - Sept. 1985            |       |       |       |       |       |       |

Table III.B-6 continued.

| REPLICATE           | 1    |      | 2    |      | 3    |      |
|---------------------|------|------|------|------|------|------|
| SIEVE FRACTION (mm) | 1.0  | 0.5  | 1.0  | 0.5  | 1.0  | 0.5  |
| Species/Fraction    | 45   | 31   | 58   | 37   | 50   | 47   |
| Species/Sample      | 63   |      | 79   |      | 65   |      |
| Individual/Fraction | 1580 | 1430 | 2660 | 2090 | 2560 | 2980 |
| Total Individuals   | 3138 |      | 4952 |      | 5775 |      |

Table III.8-7

Total Number Of Individuals And Species  
In The 0.5 mm And 0.3 mm Sieve Fractions (33.2 cm<sup>2</sup> Core)  
At FADS In June And September 1985

| STATION                  | Mud Ref   |       | Sand Ref        |       | Mud Ref    |       |
|--------------------------|-----------|-------|-----------------|-------|------------|-------|
| GRID LOCATION            | 18-17     |       | 700m E of 12-20 |       | 18-17      |       |
| DATE                     | June 1985 |       | Sept. 1985      |       | Sept. 1985 |       |
| SIEVE SIZE               | 0.5mm     | 0.3mm | 0.5mm           | 0.3mm | 0.5mm      | 0.3mm |
| Total No. of Individuals | 23        | 5     | 45              | 23    | 21         | 24    |
| Total No. of Species     | 14        | 2     | 21              | 8     | 11         | 14    |

| STATION                  | Sand Station |       | Mud Station on DM |       | Mud Station off DM |       |
|--------------------------|--------------|-------|-------------------|-------|--------------------|-------|
| GRID LOCATION            | 5-9          |       | 9-8               |       | 16-11              |       |
| DATE                     | Sept. 1985   |       | Sept. 1985        |       | Sept. 1985         |       |
| SIEVE SIZE               | 0.5mm        | 0.3mm | 0.5mm             | 0.3mm | 0.5mm              | 0.3mm |
| Total No. of Individuals | 22           | 5     | 74                | 18    | 11                 | 8     |
| Total No. of Species     | 15           | 3     | 17                | 8     | 7                  | 3     |

TABLE III.B-8

Summary Of Mean Density And Of Species Per Station Per Season At FADS.

| SITE and<br>COLLECTION DATE                  | Mean Density<br>(#/m <sup>2</sup> ) | No. of species |
|--|-------------------------------------|----------------|
| Mud Ref (18-17)<br>June 1985                 | 4344                                | 35             |
| Sand Ref *<br>September 1985                 | 9190                                | 63             |
| Sand Station (5-9)<br>September 1985         | 4622                                | 69             |
| Mud Station on DM (9-8)<br>September 1985    | 26548                               | 55             |
| Mud Station off DM (16-11)<br>September 1985 | 8746                                | 37             |
| Mud Ref (18-17)<br>September 1985            | 9218                                | 43             |
| Sand Ref *<br>January 1986                   | 11907                               | 125            |
| Mud Ref (18-17)<br>January 1986              | 4246                                | 54             |

DM = Dredged Material

\* = 700 meters east of station 12-20

TABLE III.B-9

Mean Abundance (No./m<sup>2</sup>) Of Selected Taxa At FADS In September 1985

| STATION                        | Mud Sta.<br>on DM | Mud Sta.<br>off DM | Mud Ref. | Sand Ref<br>700m E. | Sand Sta. |
|--------------------------------|-------------------|--------------------|----------|---------------------|-----------|
| GRID LOCATION                  | 9-8               | 16-11              | 18-17    | of 12-20            | 5-9       |
| SPECIES                        |                   |                    |          |                     |           |
| RHYNCHOCOELA                   | 143               | 278                | 268      | 20                  | 34        |
| ANNELIDA                       |                   |                    |          |                     |           |
| <u>Oligochaeta sp.</u>         | 6560              | 1095               | 587      | 45                  | 10        |
| Polychaeta                     |                   |                    |          |                     |           |
| Ampharetidae                   |                   |                    |          |                     |           |
| <u>Anobothrus gracilis</u>     | 1264              | 52                 | 274      | 1285                | 45        |
| Capitellidae                   |                   |                    |          |                     |           |
| <u>Heteromastus filiformis</u> | 250               | 664                | 472      | 10                  | 7         |
| <u>Mediomastus ambiseta</u>    | 1832              | 722                | 657      | 149                 | 139       |
| Cirratulidae                   |                   |                    |          |                     |           |
| <u>Chaetozone setosa</u>       | 2252              | 792                | 730      | 59                  | 10        |
| <u>Tharyx marioni</u>          | 445               | 107                | 159      | 21                  | 21        |
| Cossuridae                     |                   |                    |          |                     |           |
| <u>Cossura longocirrata</u>    | 920               | 414                | 500      | 115                 | 55        |
| Lumbrineridae                  |                   |                    |          |                     |           |
| <u>Ninoe nigripes</u>          | 167               | 59                 | 107      | 7                   | 18        |
| Nephtyidae                     |                   |                    |          |                     |           |
| <u>Nephtys incisa</u>          | 80                | 38                 | 39       | 7                   | 21        |
| Oweniidae                      |                   |                    |          |                     |           |
| <u>Myriochele oculata</u>      | 156               | 76                 | 73       | 216                 | 91        |
| Paraonidae                     |                   |                    |          |                     |           |
| <u>Aricidea quadrilobata</u>   | 1477              | 365                | 459      | 34                  | 7         |
| <u>Levinsenia gracilis</u>     | 754               | 1650               | 1880     | 563                 | 365       |
| Sigalionidae                   |                   |                    |          |                     |           |
| <u>Pholoe minuta</u>           | 128               | 10                 | 28       | 177                 | 219       |
| Spionidae                      |                   |                    |          |                     |           |
| <u>Prionospio steenstrupi</u>  | 1561              | 566                | 761      | 1324                | 326       |
| <u>Spio pettibonae</u>         | 4803              | 229                | 274      | 122                 | 45        |
| Sternaspidae                   |                   |                    |          |                     |           |
| <u>Sternaspis fossor</u>       | 3                 | 347                | 493      | 24                  | 10        |

Table III.B-9 continued.

| STATION                          | Mud Sta.<br>on DM | Mud Sta.<br>off DM | Mud Ref. | Sand Ref<br>700m E. | Sand Sta. |
|----------------------------------|-------------------|--------------------|----------|---------------------|-----------|
| GRID LOCATION                    | 9-8               | 16-11              | 18-17    | of 12-20            | 5-9       |
| SPECIES                          |                   |                    |          |                     |           |
| Syllidae                         |                   |                    |          |                     |           |
| <u>Exogone verugera profunda</u> | 188               | 52                 | 55       | 1418                | 945       |
| Trochochaetidae                  |                   |                    |          |                     |           |
| <u>Trochochaeta multisetosa</u>  | 625               | 180                | 351      | 3                   | 3         |
| MOLLUSCA                         |                   |                    |          |                     |           |
| Bivalvia                         |                   |                    |          |                     |           |
| Thyasiridae                      |                   |                    |          |                     |           |
| <u>Thyasira flexuosa</u>         | 1018              | 320                | 472      | 14                  | 49        |



TABLE III.B-10

Mean Abundance (No./m<sup>2</sup>) Of Selected Taxa At FADS Reference Station In June And September 1985 And January 1986.

| STATION                        | Mud<br>Ref   | Mud<br>Ref    | Mud<br>Ref      | Sand<br>Ref            | Sand<br>Ref              |
|--------------------------------|--------------|---------------|-----------------|------------------------|--------------------------|
| GRID LOCATION                  | 18-17        | 18-17         | 18-17           | 700mE.                 | 700mE.                   |
| DATE                           | June<br>1985 | Sept.<br>1985 | January<br>1986 | of 12-20<br>Sept. 1985 | of 12-20<br>January 1986 |
| SPECIES                        |              |               |                 |                        |                          |
| RHYNCHOCOELA                   | 70           | 268           | 87              | 20                     | 10                       |
| ANNELIDA                       |              |               |                 |                        |                          |
| <u>Oligochaeta sp.</u>         | 212          | 587           | 197             | 45                     | 57                       |
| Polychaeta                     |              |               |                 |                        |                          |
| Ampharetidae                   |              |               |                 |                        |                          |
| <u>Anobothrus gracilis</u>     | 21           | 274           | 100             | 1285                   | 884                      |
| Capitellidae                   |              |               |                 |                        |                          |
| <u>Heteromastus filiformis</u> | 570          | 472           | 546             | 472                    | 25                       |
| <u>Mediomastus ambiseta</u>    | 107          | 657           | 110             | 149                    | 477                      |
| Cirratulidae                   |              |               |                 |                        |                          |
| <u>Chaetozone setosa</u>       | 167          | 730           | 197             | 59                     | 83                       |
| <u>Tharyx marioni</u>          | 56           | 159           | 187             | 21                     | 175                      |
| Cossuridae                     |              |               |                 |                        |                          |
| <u>Cossura longocirrata</u>    | 310          | 500           | 213             | 115                    | 183                      |
| Lumbrineridae                  |              |               |                 |                        |                          |
| <u>Ninoe nigripes</u>          | 63           | 107           | 83              | 7                      | 10                       |
| Nephtyidae                     |              |               |                 |                        |                          |
| <u>Nephtys incisa</u>          | 7            | 39            | 14              | 7                      | 3                        |
| Oweniidae                      |              |               |                 |                        |                          |
| <u>Myriochele oculata</u>      | 87           | 73            | 151             | 216                    | 646                      |
| Paraonidae                     |              |               |                 |                        |                          |
| <u>Aricidea quadrilobata</u>   | 70           | 459           | 126             | 34                     | 57                       |
| <u>Levinsenia gracilis</u>     | 1689         | 1880          | 1239            | 563                    | 636                      |
| Sigalionidae                   |              |               |                 |                        |                          |
| <u>Pholoe minuta</u>           | 10           | 28            | 7               | 177                    | 116                      |
| Spionidae                      |              |               |                 |                        |                          |
| <u>Prionospio steenstrupi</u>  | 70           | 761           | 107             | 1324                   | 2692                     |
| <u>Spio pettibonae</u>         | 285          | 274           | 251             | 122                    | 255                      |

Table III.B-10 continued.

| STATION                          | Mud<br>Ref   | Mud<br>Ref    | Mud<br>Ref      | Sand<br>Ref        | Sand<br>Ref        |
|----------------------------------|--------------|---------------|-----------------|--------------------|--------------------|
| GRID LOCATION                    | 18-17        | 18-17         | 18-17           | 700mE.<br>of 12-20 | 700mE.<br>of 12-20 |
| DATE                             | June<br>1985 | Sept.<br>1985 | January<br>1986 | Sept.<br>1985      | January<br>1986    |
| SPECIES                          |              |               |                 |                    |                    |
| Sternaspidae                     |              |               |                 |                    |                    |
| <u>Sternaspis fossor</u>         | 59           | 493           | 126             | 24                 | 18                 |
| Syllidae                         |              |               |                 |                    |                    |
| <u>Exogone verugera profunda</u> | 10           | 55            | 3               | 1418               | 1850               |
| Trochochaetidae                  |              |               |                 |                    |                    |
| <u>Trochochaeta multisetosa</u>  | 66           | 351           | 129             | 3                  | 10                 |
| MOLLUSCA                         |              |               |                 |                    |                    |
| Bivalvia                         |              |               |                 |                    |                    |
| Thyasiridae                      |              |               |                 |                    |                    |
| <u>Thyasira flexuosa</u>         | 45           | 472           | 119             | 14                 | 32                 |

Table III.B-11

Mean Density Of Oligochaetes, And Top 3 Species  
Of Polychaetes, Crustaceans And Molluscs (plus Arctica)  
Per Season At The Mud Reference (18-17) Station

Species Mean Density (#/m<sup>2</sup>)

June 1985

|                                |      |
|--------------------------------|------|
| Oligochaeta                    | 212  |
| Polychaeta                     |      |
| <u>Levinsenia gracilis</u>     | 1689 |
| <u>Heteromastus filiformis</u> | 570  |
| <u>Cossura longocirrata</u>    | 310  |
| Mollusca                       |      |
| <u>Thyasira Flexuosa</u>       | 45   |
| <u>Chaetoderma nitidulum</u>   | 18   |
| <u>Siphonodentalium</u> sp.    | 10   |
| <u>Arctica islandica</u>       | 0    |
| Crustacea                      |      |
| <u>Harpinia propinqua</u>      | 3    |
| <u>Photis reinhardi</u>        | 3    |
| <u>Eudorella hispida</u>       | 3    |

September 1985

|                               |      |
|-------------------------------|------|
| Oligochaeta                   | 587  |
| Polychaeta                    |      |
| <u>Levinsednia gracilis</u>   | 1880 |
| <u>Prionospio steenstrupi</u> | 761  |
| <u>Chaetozone setosa</u>      | 730  |
| Mollusca                      |      |
| <u>Thyasira flexuosa</u>      | 472  |
| <u>Nucula tenuis</u>          | 42   |
| <u>Yoldia thraciaeformis</u>  | 18   |
| <u>Arctica islandica</u>      | 0    |
| Crustacea                     |      |
| <u>Harpinia propinqua</u>     | 28   |
| <u>Leucon Nasicoides</u>      | 18   |
| <u>Erichthonius</u> sp.       | 14   |

January 1986

|                                |      |
|--------------------------------|------|
| Oligochaeta                    | 191  |
| Polychaeta                     |      |
| <u>Levinsenia gracilis</u>     | 1281 |
| <u>Heteromastus filiformis</u> | 528  |
| <u>Spio pettibonae</u>         | 243  |
| Mollusca                       |      |
| <u>Thyasira flexuosa</u>       | 115  |
| <u>Nucula delphinodonta</u>    | 6    |
| <u>Portlandia lenticula</u>    | 6    |
| <u>Arctica islandica</u>       | 3    |
| Crustacea                      |      |
| <u>Harpinia propinqua</u>      | 23   |
| <u>Eudorella</u> sp. A         | 23   |
| <u>Eudorella trumculata</u>    | 3    |

Table III.B-12

Mean Density Of Oligochaetes, And Top 3 Species  
Of Polychaetes, Crustaceans And Molluscs (plus Arctica) Per  
Season At The Sand Reference Station (700 Meters East of 12-20)

September 1985

| Species                               | Mean Density (#/m <sup>2</sup> ) |
|---------------------------------------|----------------------------------|
| Oligochaeta                           | 45                               |
| Polychaeta                            |                                  |
| <u>Exogone verugera profunda</u>      | 1419                             |
| <u>Prionospio steenstrupi</u>         | 1324                             |
| <u>Anobothrus gracilis</u>            | 1285                             |
| Mollusca                              |                                  |
| <u>Astarte undata</u>                 | 222                              |
| <u>Crenella decussata</u>             | 94                               |
| <u>Astarte crenata subiequilatera</u> | 83                               |
| <u>Arctica islandica</u>              | 0                                |
| Crustacea                             |                                  |
| <u>Calathura branchiata</u>           | 132                              |
| <u>Haploops tubicola</u>              | 101                              |
| <u>Harpinia propinqua</u>             | 63                               |

January 1986

|                                  |      |
|----------------------------------|------|
| Oligochaeta                      | 55   |
| Polychaeta                       |      |
| <u>Prionospio steenstrupi</u>    | 2601 |
| <u>Exogone verugera profunda</u> | 1790 |
| <u>Anobothrus gracilis</u>       | 855  |
| Mollusca                         |      |
| <u>Arctica islandica</u>         | 186  |
| <u>Astarte undata</u>            | 186  |
| <u>Crenella decussata</u>        | 161  |
| Crustacea                        |      |
| <u>Harpinia propinqua</u>        | 331  |
| <u>Haploops tubicola</u>         | 281  |
| <u>Aeginina longicornis?</u>     | 126  |

TABLE III.B-13

Percent Contribution Of The Total Mean Abundance By Categories  
Per Station Per Season At FADS

| Site<br>Date | Mud Ref<br>June 1985 | Sand Ref<br>Sept. 1985 | Sand Station<br>Sept. 1985 | Mud Station on DM<br>Sept. 1985 |
|--------------|----------------------|------------------------|----------------------------|---------------------------------|
| POLYCHAETA   | 92.5%                | 84.5%                  | 76.4%                      | 70.3%                           |
| OLIGOCHAETA  | 4.9%                 | 0.05%                  | 0.2%                       | 24.7%                           |
| CRUSTACEA    | 0.2%                 | 4.2%                   | 6.7%                       | 0.43%                           |
| MOLLUSCA     | 1.8%                 | 8.3%                   | 13.1%                      | 4.3%                            |
| OTHERS       | 0.5%                 | 2.0%                   | 3.3%                       | 0.15%                           |

| Site<br>Date | Mud Station off DM<br>Sept. 1985 | Mud Ref<br>Sept. 1985 | Sand Ref<br>Jan. 1986 | Mud Ref<br>Jan. 1986 |
|--------------|----------------------------------|-----------------------|-----------------------|----------------------|
| POLYCHAETA   | 81.2%                            | 85.8%                 | 84.7%                 | 89.2%                |
| OLIGOCHAETA  | 12.8%                            | 6.5%                  | 0.45%                 | 4.6%                 |
| CRUSTACEA    | 0.39%                            | 0.84%                 | 8.6%                  | 1.0%                 |
| MOLLUSCA     | 4.9%                             | 6.5%                  | 5.5%                  | 3.7%                 |
| OTHERS       | 0.52%                            | 0.26%                 | 0.68%                 | 1.3%                 |

DM = Dredged Material

Table III.B-14

Rank Abundance Of Top Ten Species At The Mud Reference (18-17) Station Per Season At FADS

|     | <u>June 1985</u>               | <u>Mean Density #/m<sup>2</sup></u> | <u>September 1985</u>          | <u>Mean Density #/m<sup>2</sup></u> |
|-----|--------------------------------|-------------------------------------|--------------------------------|-------------------------------------|
| 1.  | <u>Levinsenia gracilis</u>     | 1689                                | <u>Levinsenia gracilis</u>     | 1880                                |
| 2.  | <u>Heteromastus filiformis</u> | 570                                 | <u>Prionospio steenstrupi</u>  | 761                                 |
| 3.  | <u>Cossura longocirrata</u>    | 310                                 | <u>Chaetozone setosa</u>       | 730                                 |
| 4.  | <u>Spio pettibonae</u>         | 284                                 | <u>Mediomastus ambiseta</u>    | 587                                 |
| 5.  | <u>Oligochaeta</u>             | 212                                 | <u>Oligochaeta</u>             | 587                                 |
| 6.  | <u>Chaetozone setosa</u>       | 167                                 | <u>Cossura longocirrata</u>    | 500                                 |
| 7.  | <u>Mediomastus ambiseta</u>    | 107                                 | <u>Sternaspis fossor</u>       | 493                                 |
| 8.  | <u>Myriochele oculata</u>      | 86                                  | <u>Thyasira flexuosa</u>       | 472                                 |
| 9.  | <u>Prionospio steenstrupi</u>  | 70                                  | <u>Heteromastus filiformis</u> | 472                                 |
| 10. | <u>Aricidea quadrilobata</u>   | 70                                  | <u>Aricidea quadrilobata</u>   | 459                                 |

Table III.B-14 (cont.)

|     | January 1986                   | Mean Density #/m <sup>2</sup> |
|-----|--------------------------------|-------------------------------|
| 1.  | <u>Levinsonia gracilis</u>     | 1239                          |
| 2.  | <u>Heteromastus filiformis</u> | 546                           |
| 3.  | <u>Spio pettibonae</u>         | 251                           |
| 4.  | <u>Cossura longocirrata</u>    | 213                           |
| 5.  | <u>Oligochaeta</u>             | 197                           |
| 6.  | <u>Chaetozone setosa</u>       | 197                           |
| 7.  | <u>Tharyx</u> sp.              | 187                           |
| 8.  | <u>Myriochele oculata</u>      | 151                           |
| 9.  | <u>Aricidea quadrilobata</u>   | 126                           |
| 10. | <u>Sternaspis fessor</u>       | 126                           |

Table III.B-15

Rank Abundance Of Top Ten Species At The Sand Reference Station Per Season At FADS

|     | <u>September 1985</u>            | <u>Mean Density #/m<sup>2</sup></u> | <u>January 1986</u>              | <u>Mean Density #/m<sup>2</sup></u> |
|-----|----------------------------------|-------------------------------------|----------------------------------|-------------------------------------|
| 1.  | <u>Exogone venugera profunda</u> | 1418                                | <u>Prionospio steenstrupi</u>    | 2692                                |
| 2.  | <u>Prionospio steenstrupi</u>    | 1324                                | <u>Exogone venugera profunda</u> | 1850                                |
| 3.  | <u>Anobothrus gracilis</u>       | 1285                                | <u>Anobothrus gracilis</u>       | 884                                 |
| 4.  | <u>Praxillella longissima</u>    | 570                                 | <u>Myriochele oculata</u>        | 646                                 |
| 5.  | <u>Levinsonia gracilis</u>       | 563                                 | <u>Levinsonia gracilis</u>       | 636                                 |
| 6.  | <u>Ampharetidae</u>              | 521                                 | <u>Praxillella longissima</u>    | 614                                 |
| 7.  | <u>Myriochele oculata</u>        | 216                                 | <u>Exogone hebes</u>             | 611                                 |
| 8.  | <u>Astarte undata</u>            | 222                                 | <u>Mediomastus ambiseta</u>      | 477                                 |
| 9.  | <u>Chone infundibuliformis</u>   | 185                                 | <u>Harpinia prooingua</u>        | 320                                 |
| 10. | <u>Pholoe minuta</u>             | 177                                 | <u>Haploops tubicola</u>         | 291                                 |



TABLE III.B-16  
ANOVA Results For Fourth Root Transformed Data  
Of FADS Dominant Taxa

| SPECIES                           | Among<br>Stations<br>Sept. 1985 | Among<br>Seasons<br>Mud Reference |
|-----------------------------------|---------------------------------|-----------------------------------|
| Annelida                          |                                 |                                   |
| <u>Oligochaeta</u> sp.            | ***                             | NS                                |
| Polychaeta                        |                                 |                                   |
| Ampharetidae                      |                                 |                                   |
| <u>Anobothrus gracillis</u>       | ***                             | ***                               |
| Capitellidae                      |                                 |                                   |
| <u>Heteromastus filliliformis</u> | ***                             | NS                                |
| <u>Mediomastus ambiseta</u>       | **                              | *                                 |
| Cirratulidae                      |                                 |                                   |
| <u>Chaetozone setosa</u>          | ***                             | **                                |
| Paraonidae                        |                                 |                                   |
| <u>Levinsenia gracilis</u>        | ***                             | NS                                |
| <u>Aricidea quadrilobata</u>      | ***                             | **                                |
| Spionidae                         |                                 |                                   |
| <u>Prionospio steenstrupi</u>     | NS                              | **                                |
| <u>Spio pettibonae</u>            | ***                             | NS                                |
| Syllidae                          |                                 |                                   |
| <u>Exogone verugera</u>           | ***                             | *                                 |
| Mollusca                          |                                 |                                   |
| Bivalvia                          |                                 |                                   |
| Thyrasiridae                      |                                 |                                   |
| <u>Thyasira flexuosa</u>          | ***                             | *                                 |
| Species/Sample                    | **                              | NS                                |
| Total Individuals/Sample          | ***                             | *                                 |

\* p<.05  
 \*\* p<.01  
 \*\*\* p<.001  
 NS Not Significant

TABLE III.B-17  
Scheffé Test Results Of ANOVAS For Dominant Taxa At FADS  
September 1985

(Stations connected by lines are statistically similar.)

| SPECIES                          | Mud<br>Station<br>On DM (9-8) | Mud<br>Reference<br>(18-17) | Mud<br>Station<br>Off DM(16-11) | Sand<br>Station<br>(5-9) | Sand<br>Reference |
|----------------------------------|-------------------------------|-----------------------------|---------------------------------|--------------------------|-------------------|
| Arnelida                         |                               |                             |                                 |                          |                   |
| <u>Oligochaeta</u> sp.           |                               |                             |                                 |                          |                   |
| Polychaeta                       |                               |                             |                                 |                          |                   |
| Ampharetidae                     |                               |                             |                                 |                          |                   |
| <u>Anobothrus gracilis</u> *     |                               |                             |                                 |                          |                   |
| Capitellidae                     |                               |                             |                                 |                          |                   |
| <u>Heteromastus filiformis</u>   |                               |                             |                                 |                          |                   |
| <u>Mediomastus ambiseta</u>      |                               |                             |                                 |                          |                   |
| Cirratulidae                     |                               |                             |                                 |                          |                   |
| <u>Chaetozone setosa</u>         |                               |                             |                                 |                          |                   |
| Paraonidae                       |                               |                             |                                 |                          |                   |
| <u>Levensenia gracilis</u>       |                               |                             |                                 |                          |                   |
| <u>Aricidea quadrilobata</u>     |                               |                             |                                 |                          |                   |
| Spionidae                        |                               |                             |                                 |                          |                   |
| <u>Prionospio steenstrupi</u>    |                               |                             |                                 |                          |                   |
| <u>Spio pettibonae</u>           |                               |                             |                                 |                          |                   |
| Syllidae                         |                               |                             |                                 |                          |                   |
| <u>Exogone venugera profunda</u> |                               |                             |                                 |                          |                   |
| Mollusca                         |                               |                             |                                 |                          |                   |
| Bivalvia                         |                               |                             |                                 |                          |                   |
| Thyasiridae                      |                               |                             |                                 |                          |                   |
| <u>Thyasira flexuosa</u>         |                               |                             |                                 |                          |                   |
| Species/Sample                   |                               |                             |                                 |                          |                   |
| Total Individuals/Sample         |                               |                             |                                 |                          |                   |

\* Mud Station On DM and Sand Reference similar for this taxon.

TABLE III.B-18  
Scheffé Test Results Of ANOVAS For Dominant Taxa  
At Mud Reference Station At FADS

(Dates connected by lines are statistically similar.)

| SPECIES                          | June 1985 | January 1986 | September 1985 |
|----------------------------------|-----------|--------------|----------------|
| Annelida                         |           |              |                |
| <u>Oligochaeta sp.</u>           |           |              |                |
| Polychaeta                       |           |              |                |
| Ampharetidae                     |           |              |                |
| <u>Anobothrus gracilis</u>       |           |              |                |
| Capitellidae                     |           |              |                |
| <u>Heteromastus filiformis</u>   |           |              |                |
| <u>Mediomastus ambiseta</u>      |           |              |                |
| Cirratulidae                     |           |              |                |
| <u>Chaetozone setosa</u>         |           |              |                |
| Paraonidae                       |           |              |                |
| <u>Levinsenia gracilis</u>       |           |              |                |
| <u>Aricidea quadrilobata</u>     |           |              |                |
| Spionidae                        |           |              |                |
| <u>Prionospio steenstrupi</u>    |           |              |                |
| <u>Spio pettibonae</u>           |           |              |                |
| Syllidae                         |           |              |                |
| <u>Exogone verugera profunda</u> |           |              |                |
| Mollusca                         |           |              |                |
| Bivalvia                         |           |              |                |
| Thyasiridae                      |           |              |                |
| <u>Thyasira flexuosa</u>         |           |              |                |
| Species/Sample                   |           |              |                |
| Total Individuals/Sample         |           |              |                |

Table III.B-19

Observations of Invertebrates (#/m<sup>2</sup>) From Submersible Transects  
Foul Area Disposal Site, June 1985

| Dive<br>Habitats<br>Area m <sup>2</sup> | 1-2<br>SE Mud/Clay<br>388.3m <sup>2</sup> | 2-3<br>Dredge Material<br>44m <sup>2</sup> | 3-4<br>NE Mud/Clay<br>188.6m <sup>2</sup> | 3-4<br>NE Cobble<br>246.6m <sup>2</sup> |
|---|---|--|---|---|
| SPECIES                                 |   |  |   |   |
| PORIFERA                                |   |  |   |   |
| Halichondridae                          |   |  |   |   |
| <u>Halichondria</u> sp.                 | -   | -  | 0.87                                      | 3.04                                    |
| CNIDARIA                                |   |  |   |   |
| Actinidae                               |   |  |   |   |
| <u>Tealia</u> sp.                       | -   | -  | 0.03                                      | 0.01                                    |
| Ceriantharidae                          |   |  |   |   |
| Cerianthid (sm.)                        | -   | -  | 2.56                                      | 12.40                                   |
| Cerianthid (lg.)                        | .003                                      | -  | 0.76                                      | 2.32                                    |
| Cerianthid tubes                        | -   | -  | 1.34                                      | 1.31                                    |
| ANNELIDA                                |   |  |   |   |
| Polychaeta                              |   |  |   |   |
| Sabellidae                              |   |  |   |   |
| <u>Myxicola</u> sp.                     | -   | -  | 0.56                                      | 7.13                                    |
| BRACHIOPODA                             |   |  |   |   |
| <u>Terebratulina</u> sp.                | -   | -  | -   | 0.09                                    |
| MOLLUSCA                                |   |  |   |   |
| Bivalvia                                |   |  |   |   |
| Pectinidae                              |   |  |   |   |
| <u>Placopecten</u> sp.                  | -   | -  | -   | 0.01                                    |
| ARTHROPODA                              |   |  |   |   |
| Crustacea                               |   |  |   |   |
| Caridea                                 |   |  |   |   |
| Pandalidae                              |   |  |   |   |
| Pandalid (sm.)                          | 6.40                                      | 2.16                                       | 3.60                                      | 1.10                                    |
| Pandalid (lg.)                          | 0.87                                      | 0.34                                       | 0.91                                      | 0.18                                    |
| Mysidacea                               |   |  |   |   |
| Mysidae                                 |   |  |   |   |
| Mysid sp.                               | 14.1                                      | 5.80                                       | 10.60                                     | -                                       |
| Decapoda                                |   |  |   |   |
| Paguridae                               |   |  |   |   |
| <u>Pagurus</u> sp.                      | -   | 0.023                                      | -   | 0.01                                    |
| ECHINODERMATA                           |   |  |   |   |
| <u>Asterias/Leptasterias</u>            | 0.03                                      | 0.09                                       | 0.28                                      | 0.58                                    |
| Goniasteridae                           |   |  |   |   |

Table III-C-4 Seasonal mean densities of the 10 most abundant seabirds (birds/km<sup>2</sup>) with standard deviations in each season in the contiguous waters inshore of the MBDS and offshore of the MBDS

INSHORE OF THE DISPOSAL SITE

| Species                  | Winter           | Spring         | Summer        | Fall            |
|--------------------------|------------------|----------------|---------------|-----------------|
| Herring Gull             | 5.542 (18.994)   | 2.922 (6.534)  | 1.653 (3.525) | 5.540 (9.056)   |
| Great Black-backed Gull  | 5.341 (17.045)   | 1.286 (2.139)  | 2.109 (4.823) | 3.988 (6.574)   |
| Black-legged Kittiwake   | 6.729 (34.865)   | 0.307 (0.998)  |               | 4.981 (15.690)  |
| Northern Fulmar          |                  | 0.245 (1.091)  |               |                 |
| Common Eider             | 1.124 (5.513)    | 1.143 (4.918)  |               | 7.605 (47.649)  |
| Oldsquaw                 | 0.138 (1.032)    | 5.152 (20.928) |               | 13.836 (90.908) |
| White-winged Scoter      | 16.450 (113.699) | 0.230 (1.346)  | 0.047 (0.412) | 0.689 (2.760)   |
| Surf Scoter              |                  | 0.094 (0.548)  |               | 0.389 (2.733)   |
| Ring-billed Gull         |                  |                |               |                 |
| Bonaparte's Gull         | 1.090 (6.991)    |                |               | 0.846 (3.153)   |
| Laughing Gull            |                  |                | 0.053 (0.350) |                 |
| Common Tern              |                  |                | 0.044 (0.241) |                 |
| Common Loon              |                  |                | 0.031 (0.204) |                 |
| Red-throated Loon        |                  |                |               |                 |
| Red-breasted Merganser   | 0.173 (1.165)    |                |               |                 |
| Alcidae spp.             | 0.229 (1.087)    | 0.322 (0.804)  |               |                 |
| Cory's Shearwater        |                  |                | 0.037 (0.330) |                 |
| Greater Shearwater       |                  |                | 2.547 (8.940) |                 |
| Sooty Shearwater         |                  |                | 0.375 (1.425) |                 |
| Wilson's Storm-Petrel    |                  |                | 2.950 (6.549) |                 |
| Northern Phalarope       |                  |                |               |                 |
| Pomarine Jaeger          |                  |                |               |                 |
| Double-crested Cormorant | 0.785 (1.431)    | 0.155 (0.352)  |               |                 |
| Northern Gannet          |                  |                |               | 2.300 (6.027)   |

Table III-C-4 continued)

## OFFSHORE OF THE DISPOSAL SITE

| Species                  | Winter         | Spring        | Summer         | Fall            |
|--------------------------|----------------|---------------|----------------|-----------------|
| Herring Gull             | 2.148 (2.806)  | 7.312(19.893) | 7.640(25.079)  | 32.538 (95.698) |
| Great Black-backed Gull  | 4.714 (8.753)  | 7.209(22.514) | 3.325(12.721)  | 5.616 (8.586)   |
| Black-legged Kittiwake   | 12.651(52.138) | 0.849 (2.359) |                | 52.579(149.995) |
| Northern Fulmar          | 0.334 (1.552)  | 0.130 (0.360) |                | 0.491 (1.502)   |
| Common Eider             | 0.218 (1.617)  | 0.123 (0.489) |                | 0.207 (1.077)   |
| Oldsquaw                 | 0.163 (0.917)  |               |                | 0.066 (0.346)   |
| White-winged Scoter      |                |               |                |                 |
| Surf Scoter              |                |               | 0.041 (0.248)  |                 |
| Ring-billed Gull         |                |               |                |                 |
| Bonaparte's Gull         | 0.196 (1.456)  |               |                | 0.152 (0.791)   |
| Laughing Gull            | 0.049 (0.364)  |               | 0.147 (0.731)  |                 |
| Common Tern              |                | 0.007 (0.381) |                |                 |
| Common Loon              |                | 0.090 (0.291) |                |                 |
| Red-throated Loon        |                | 0.037 (0.212) |                |                 |
| Red-breasted Merganser   |                | 0.269 (1.527) |                |                 |
| Alcidae spp.             | 1.847(10.282)  |               | 0.035 (0.219)  |                 |
| Cory's Shearwater        |                |               | 3.640(13.743)  | 65.532(204.160) |
| Greater Shearwater       |                |               | 0.085 (0.280)  |                 |
| Sooty Shearwater         |                |               | 11.224(23.030) |                 |
| Wilson's Storm Petrel    |                |               | 0.162 (1.394)  |                 |
| Northern Phalarope       |                |               |                | 0.076 (0.395)   |
| Pomarine Jaeger          |                |               | 0.251 (1.826)  |                 |
| Double-crested Cormorant |                |               |                | 3.317 (3.394)   |
| Northern Gannet          | 0.920 (1.760)  | 1.110 (1.447) |                |                 |

Table III-C-4b Seasonal mean densities of the 10 most abundant seabirds (birds/km<sup>2</sup>) with standard deviations in each season in the contiguous waters inshore of the CADS and offshore of the CADS.

INSHORE OF THE DISPOSAL SITE

| Species                  | Winter        | Spring<br>(No Data) | Summer        | Fall          |
|--------------------------|---------------|---------------------|---------------|---------------|
| Herring Gull             | 2.758 (7.587) |                     | 0.718 (0.864) | 1.842 (1.368) |
| Great Black-backed Gull  | 3.980(10.467) |                     | 1.608 (1.369) | 0.474 (0.685) |
| Black-legged Kittiwake   | 5.693(13.302) |                     |               |               |
| Iceland Gull             | 0.050 (0.200) |                     |               |               |
| Northern Fulmar          | 0.343 (1.004) |                     |               |               |
| Common Eider             | 1.350 (3.904) |                     |               |               |
| Oldsquaw                 | 0.105 (0.340) |                     |               | 1.028 (2.721) |
| White-winged Scoter      | 0.146 (0.591) |                     |               | 0.457 (1.209) |
| Greater Shearwater       | 0.028 (0.159) |                     |               | 0.114 (0.302) |
| Alcidae spp.             | 0.252 (0.692) |                     |               | 0.228 (0.604) |
| Wilson's Storm-Petrel    |               |                     | 0.440 (1.166) | 2.203 (5.391) |
| Arctic Tern              |               |                     | 0.257 (0.680) |               |
| Northern Phalarope       |               |                     | 3.820(10.107) |               |
| Northern Gannet          |               |                     | 0.228 (0.604) | 0.319 (0.576) |
| Pomarine Jaeger          |               |                     | 0.114 (0.302) |               |
| Common Loon              |               |                     |               | 0.114 (0.302) |
| Glaucous Gull            |               |                     |               |               |
| Black Scoter             |               |                     |               |               |
| Double-crested Cormorant |               |                     |               |               |
| Red-throated Loon        |               |                     |               |               |
| Sooty Shearwater         |               |                     |               |               |
| Common Tern              |               |                     |               |               |
| Leach's Storm-Petrel     |               |                     |               |               |

Table III-C-4b (continued)

## OFFSHORE OF THE DISPOSAL SITE

| Species                  | Winter        | Spring        | Summer        | Fall          |
|--------------------------|---------------|---------------|---------------|---------------|
| Herring Gull             | 5.442(12.656) | 1.443 (2.239) | 2.647 (8.633) | 2.288 (4.100) |
| Great Black-backed Gull  | 7.028(16.651) | 1.170 (1.880) | 1.913 (5.015) | 5.253(13.604) |
| Black-legged Kittiwake   | 7.953(20.867) |               |               | 1.424 (3.162) |
| Iceland Gull             |               |               |               |               |
| Northern Fulmar          | 1.169 (5.837) | 0.080 (0.272) |               | 0.045 (0.270) |
| Common Eider             | 0.516 (2.274) |               |               | 0.918 (2.479) |
| Oldsquaw                 |               |               |               | 0.051 (0.304) |
| White-winged Scoter      | 0.043 (0.371) |               |               |               |
| Greater Shearwater       |               |               | 0.901 (1.985) | 0.259 (0.868) |
| Alcidae spp.             |               |               |               |               |
| Wilson's Storm-Petrel    | 0.819 (6.071) | 0.040 (0.200) | 3.764 (7.498) |               |
| Arctic Tern              |               |               |               |               |
| Northern Phalarope       |               | 0.156 (1.061) |               |               |
| Northern Gannet          | 0.136 (0.341) | 0.845 (1.232) | 0.038 (0.183) | 1.847 (2.351) |
| Pomarine Jaeger          |               |               | 0.017 (0.117) |               |
| Common Loon              |               | 0.205 (0.575) |               | 0.070 (0.237) |
| Glaucous Gull            | 0.038 (0.187) |               |               |               |
| Black Scoter             | 0.064 (0.557) |               |               |               |
| Double-crested Cormorant |               |               |               |               |
| Red-throated Loon        |               | 1.887 (8.338) |               | 0.020 (0.121) |
| Sooty Shearwater         |               | 0.044 (0.220) |               |               |
| Common Tern              |               |               | 0.170 (0.441) |               |
| Leach's Storm-Petrel     |               |               | 0.100 (0.386) |               |
|                          |               |               | 0.017 (0.117) |               |



